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APPLIED MECHANICS REVIEWS

VOL. 4, NO. 8 MARTIN GOLAND *Editor* AUGUST 1951

LUBRICATION

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THE MULTIPLE lubrication problems which are of great concern to a designing engineer include the design of bearing, selection of suitable materials, and friction and the evaluation of wear. All such problems, as one can see, are closely intermeshed since, in most of the practical cases, they are inseparable as occurring in one unit. If archaeological researches correctly indicate that the potter's wheel may have been the first mechanism incorporating a bearing—one may surmise that most of the above-mentioned problems are indeed very old. The status of the four items comprising what is usually classified as lubrication, i.e., bearings, friction, lubrication, and wear may be summarized as follows:

BEARINGS

The fundamental principle of using low melting-temperature bearing-lining material remains unchanged in all bearings operating in the fluid-film region. Cadmium-base (approximately 98% Cd) alloys proved advantageous for some heavy-duty applications because of required hardness and of much higher thermal conductivity of cadmium than the conventional tin-base and lead-base babbitts. Steel-backed silver-lined bushings with a lead lining electroplated with a thin layer in indium are widely used with non-compounded oils in aviation engines. For these applications a considerable amount of bearings lined with fine-grain copper-lead mixtures were used in Germany during World War II. Centrifugally cast bronze is gradually replacing inferior sand-cast bronze which is widely used as heavy-duty Diesel engine bearing-back material. Aluminum integral bearings are operating successfully in many Caterpillar Diesel engines. Synthetic resin-bonded bearing material is also used when lubricated and cooled with water at low unit pressures in ship stern tubes and at very high unit pressures in steel mill bearings. Considerable improvement has been achieved in anti-friction bearings with the introduction of new heat-treating processes such as martempering, which extended the life of bearings and increased the load-carrying capacity.

The many requirements imposed for satisfactory operation of journal bearings such as hardness at elevated temperatures, thermal conductivity, embeddability, fatigue, corrosion resistance, adsorption, bondability, and compressive stress indicate that there is no universal bearing material which would satisfy many of these requirements.

FRICTION

Heat-transfer problems are naturally encountered in the case of perfect fluid-film lubrication where the heat generated by shearing the oil should be carried away. Heat effects in the oil film have been discussed for a long time; additional information on this subject continues to appear from time to time. Surface finish of the rubbing areas of a bearing can be specified in order to comply with the minimum operating film thickness of a bearing. It has been shown on an experimental model of a Kingsbury bearing that pressures up to 800 pounds per square inch could be safely carried with a surface roughness of 10 microinches. Further research in connection with fluid-film lubrication includes such items as investigation of losses due to turbulence of the oil in the reliefs and in the non-loaded sections of the bearing, influence of the oil film on the stability of rotating machines, shaft whirl, shimmy phenomenon, effect or rate of shear and rational methods of oil-temperature measurements which may indicate the actual temperature of the oil at the position of the nearest approach.

A considerable amount of friction tests have been conducted in the laboratories of the National Advisory Committee for Aeronautics. Thus, experiments in the field of semi-fluid friction indicate that such compounds as molybdenum disulfide may be very useful for reducing wear and fretting corrosion. Results of many similar experiments performed on kinetic friction-type apparatus, originated by Phillip Bowden in Cambridge, England, confirmed the accepted physical principles of dry and semi-fluid friction, i.e., molecular attraction and interlocking for the former and adsorption for the latter. It should be noted that some interesting work in the field of friction was vigorously pursued in Germany during World War II. A considerable amount of such work is probably conducted beyond the Iron Curtain, judging by the few Russian technical publications.

It is obvious that there are numerous friction-test machines which have been constructed for specific purposes in order to predict operation of an actual machine element.

LUBRICATION

The classical hydrodynamic theory of lubrication, as first pre-

EDITOR'S NOTE: The eighth in a series of articles, contributed to APPLIED MECHANICS REVIEWS by international authorities, surveying important topics in applied mechanics.

sented by Reynolds in 1886 and then expanded for practical applications by the still living Sommerfeld, serves for analytical determination of the performance of bearings operating in the region of perfect film lubrication. With its use it is possible to predict the performance of a bearing with a good degree of accuracy despite the fact that the theory does not account for such as deflections, surface conditions of the sliding parts, and possible thermal stresses. The hydrodynamic theory of lubrication has been extended somewhat recently in order to account for temporal tangential bearing acceleration. This, however, seems to be of secondary importance because in practice the acceleration terms are not excessive.

Very active research has been conducted and is in progress in the field of lubricants which may be subjected in operation to high temperatures and high shearing stresses. As a result of these, the use of lubricating-oil additives in Diesel and automotive engines has been accepted. Extensive series of carefully conducted experiments have shown the need of additives such as antioxidation, detergent, antifoam and pour-point depressor compounds. Some of these were results of established new theories which were advanced to explain such commonly occurring phenomena as lubricating-oil oxidation and rust formation. The refinery technique of crude oil reached a high degree of perfection which enables chemists to manufacture finished products to meet specifications for compliance with particular molecular structure and desired final physical properties of the lubricant. Even used and discarded oils may be fully restored and reconditioned for heavy-duty operation. The viscosity and density of lubricating oils at pressures up to 150,000 psi have been experimentally determined and verified recently at Harvard, this work being sponsored by the ASME Special Research Committee on Lubrication. The wide use of greases resulted also in advanced manufacturing developments, and it is now possible to prepare a great variety of greases meeting any desired operating specification. In the high-speed field, where spindles rotate above 100,000 revolutions per minute, air or oil mist serves as the fluid which separates the rubbing surfaces. The use of palm oil in rolling tin plate, the use of extremely heavy oils for steel mill bearings, the use of turbine oils with small additions of organic acids for suppression of rust formation, and the use of synthetic materials and molten metals as lubricants should not be omitted in this review.

WEAR

Early wear tests were made to determine suitable materials for rails and for nonferrous bands of artillery shells. There exist a great number of wear-testing machines each of which has been built so as to reproduce as many as possible of the important variables affecting wear in an actual field operation. Since there are so many factors on which wear does depend, there are no universal wear-testing machines, and one is usually constructed in connection with a particular application. All these machines incorporate sliding, rolling, or a combination of both types of friction when operating under different conditions of velocity, temperature, pressure, abrasives, etc. The Standard Oil Company of California introduced a new method of piston-ring wear test, whereby the engine rings are first irradiated by the AEC, and their wear in operation is measured by Geiger counters placed in the path of crankcase-oil circulating system.

Work in the field of lubrication as described under the four above headings is conducted actively in many laboratories and establishments. Considerable experimentation will always be needed because laws of similarity fail in many friction problems; consequently, special test methods and test machines will be required for control of such variables which are specified by actual operation. Needless to say, the majority of all lubrication problems should be approached from a rather broad point of view: engineering, metallurgical, and physico-chemical. There are several colleges which, among their many technical courses, present a one-semester course in lubrication.

Communications

Concerning Rev. 1386 (March 1951): Effect of partial cutoff on seepage rates, by J. S. McNown and E.-Y. Hsu

Prof. L. J. Tison wishes to make the following correction: Rossbach treated the problem in which seepage enters an infinite stratum vertically downward and leaves in the same manner, but upward. In the problem of McNown and Hsu, the length of the stratum is finite and the flow is horizontal on entering and leaving.

Concerning Rev. 2149 (May 1951): Asymptotic expansions for the hypergeometric functions occurring in gas-flow theory, by T. M. Cherry

In the fifth line of the first paragraph, the Greek symbol should be a nu (ν).

Theoretical and Experimental Methods

(See also Revs. 3151, 3152, 3166, 3187, 3191, 3192, 3276, 3277, 3294, 3299, 3308, 3403, 3423)

3109. Wallman, H., An electronic integral-transform computer and the practical solution of integral equations, *J. Franklin Inst.* **250,** 1, 45–61, July 1950.

3110. Townsend, M. W. H., and Cox, D. R., The analysis of yarn irregularity, *J. Text. Inst. Proc.* **42,** 3, P107-P113, Mar. 1951.

Many properties of the irregularity measured in yarns are not described by the over-all variance. It is shown that the relation between the mean standardized variance $V(L)$ and length L within which $V(L)$ is measured leads to indexes characterizing the types of irregularity which may be of practical importance.

The $V(L)$ curve is also considered as an alternative expression for the correlogram, and examples are given to illustrate the relationship. The correlogram may provide the easiest method of measuring $V(L)$ and its associated indexes.

Some practical illustrations are quoted.

From authors' summary

3111. Truesdell, C., A form of Green's transformation, *Amer. J. Math.* **73,** 1, 43–47, Jan. 1951.

The author introduces the idea of a polyadic (the nth power of a vector b) such that $b^{(-1)} = 0$, $b^{(0)} = 1$, $b^{(1)} = b$, $b^{(2)} = b\,b$, $b^{(3)} = b\,b\,b$, etc. Evidently $b^{(2)}$ is the ordinary Gibbsian diadic. With this concept, he is able to obtain general transformations which reduce to special forms of Gauss' (or Greene's or Ostrogradski's) theorem, or the theorem of the divergence. No new results are obtained from these more complicated combinations; however, it may be that such general results may be useful in some hydrodynamical applications.

Lawrence Baylor Robinson, USA

3112. van Heel, A. C. S., High precision measurements with simple equipment, *J. opt. Soc. Amer.* **40,** 12, 809–816, Dec. 1950.

Three points can be aligned with a precision of 0.17 sec of arc by using only a condensed white light source and a single slit, a

double slit, and crossed wires at the three points, respectively. This precision is obtained by referring the location of the crossed wires to color transitions in the diffraction pattern which the single and double slit cause at the third point. The abbreviation "in." should be read "seconds of arc" throughout the article.

Frank McClintock, USA

3113. Scott, G. D., McLauchlan, T. A., and Sennett, R. S., The thickness measurement of thin films by multiple beam interferometry, *J. appl. Phys.* **21,** 9, 843–846, Sept. 1950.

A method is described for measuring the thickness of thin films using the multiple-beam interference techniques. Only simple equipment is required, but reduction of the order of interference to as low as *one* makes possible the measurement of average thicknesses down to 10A. Applications have been made to evaporated films of six different metals, and method appears to be useful for all stable thin films in thicknesses up to several microns. Possible errors in the method and the precautions which may be taken to avoid them are discussed. From authors' summary

3114. Greenough, M. L., and Williams, W. E., Electronic circuit for measuring the displacement of pressure-sensitive diaphragms, *J. Res. nat. Bur. Stands.* **46,** 1, 5–10, Jan. 1951.

Describes apparatus successfully employed for measurements in mass spectrometers, by the titled method. Apparatus provides 50-microamp output for diaphragm displacement of 500 microinches. Pickup is of mutual-inductance variety responding to proximity effects of thin nonmagnetic diaphragms. It exhibits low impedance and is, therefore, only slightly affected by cable length. Output is linear with respect to displacement and requires only a two-point calibration. Construction details of the mutual-inductance probe are illustrated and a complete circuit diagram and parts list for the 2.5-mc oscillator, amplifier, and power supply are presented. E. Cartotto, USA

3115. Zschaage, W., Temperature measurements in hardening (in German), *Arch. tech. Messen* **178,** V2172-2, T121-122, Nov. 1950.

3116. Schendell, G., Microscopic measurement of inaccessible dimensions in macroscopic bodies (in German), *Arch. tech. Messen* **178,** V1121-8, T120, Nov. 1950.

3117. Harrison, B. H., A low-frequency electronic integrator *David W. Taylor Mod. Basin Rep.* 725, 29 pp., Feb. 1951.

An experimental model electronic integrator employing a type of circuit common to electronic analog computers indicates favorable results when used to acquire velocity data from measurements of acceleration. Integrals of voltage as a function of time may be obtained for measurement periods of several minutes with relatively low error components. A useful frequency response up to 2000 sinusoidal cps permits reasonably accurate integration of wave forms of a transient nature. Methods and variations to solve unique application problems are suggested.

From author's summary

3118. Haag, R., On a perturbation method and its application to vibration problems (in German), *Z. angew. Math. Mech.* **31,** 1/2, 12–19, Jan.-Feb. 1951.

Assuming $x = \Sigma_{-\infty}^{+\infty} A_k e^{i(\omega+kp)}$; $A_k = \Sigma_0^{\infty} A_k^{(n)}$; $\omega = \Sigma_0^{\infty} \omega^{(n)} \lambda^{(n)}$ in order to solve the eq. $\ddot{x} + \beta\dot{x} + \omega_0^2 x + \lambda(e^{ipt} + e^{-ipt})x = 0$; λ small, by the usual methods of perturbation theory, the result fails to converge if $mp \approx 2\tilde{\omega} = 2(\omega_0^2 - \frac{1}{4}\beta^2)^{1/2}$. Writing, however, $p - 2\tilde{\omega} = q\lambda \ldots$ [1] and replacing p everywhere by the new parameter q defined in this way, comparison of coefficients of equal powers of λ yields a new recurrent system of equations defining a solution which does converge in the excluded region with $m = 1$, and which correctly reproduces the occurring instability. For $m = 2, 3$, etc., [1] should be replaced by $p - 2\tilde{\omega} = q\lambda^2$. Similarly, the equation $\ddot{x} + \beta\dot{x} + \omega_0^2 x + \lambda x^2 = K(e^{i\omega t} + e^{-i\omega t})$; λ small, cannot be solved by the methods of perturbation theory starting with $x = \Sigma_{-\infty}^{+\infty} A_k e^{ik\omega t}$; $A_k = A_{-k}^*$, if $m\omega \approx \tilde{\omega}$ (resonance). Again, a convergent result for $m = 1$ is obtainable by putting $\omega - \tilde{\omega} = q\lambda^{2/3}$; $\beta = \beta'\lambda^{2/3}$, eliminating ω and expanding into powers of $\lambda^{1/3}$. The method is said to be generalizable; it always involves the introduction of a new parameter q by a relation $p - p_{crit} = q\lambda^{\gamma}$ where p_{crit} is a critical value of an existing parameter p of the system, and γ a constant which can be determined by estimating orders of magnitude. The paper does not contain adequate references. J. H. Greidanus, Holland

3119. Flanders, D. A., and Shortley, G., Numerical determination of fundamental modes, *J. appl. Phys.* **21,** 12, 1326–1332, Dec. 1950.

Characteristic values of linear equations such as those corresponding to difference equations are found by an iterative process. Improvement over conventional procedure is obtained by iterating a polynomial function of usual operator. The Tschebyscheff polynomial is best form, but involves lower roots explicitly so that rough approximations to them have to be made.

Gilbert W. King, USA

3120. Lengyel, A., and Church, A. H., Radial disk cam design charts for maximum pressure angle, *Prod. Engng.* **22,** 3, pp. 155, 157, 159, Mar. 1951.

3121. Marks, L. S., Mechanical engineers' handbook, 5th ed., New York, Toronto, London, McGraw-Hill Book Co., Inc., 1951, xvii + 2236 pp. $15.

This is a completely revised edition of the well-known handbook. The enlarged format makes for greater legibility.

Greatly revised items include: Fluid mechanics, stresses in turbine disks, transonic and supersonic aerodynamics, aircraft jet propulsion, rockets, television, gas turbines, atomic power, automatic process control, industrial supersonics, rocket fuels, solar heating, plastics, elastomers. Ed.

3122. National Bureau of Standards, Tables relating to Mathieu functions, New York, Columbia Univ. Press, June 1951, xlvii + 278 pp. $8.

Present volume consists of an extensive set of tables of characteristic values, coefficients, and joining factors necessary for solution of Mathieu's differential equation. Its scope is more comprehensive than any other material available. The introduction gives many useful formulas and describes the use and application of the tables. Y. L. Luke, USA

3123. Brousse, P., On some properties of an elliptic type equation encountered in elasticity (in French), *C. R. Acad. Sci. Paris* **230,** 7, 713–714, Feb. 1950.

Author finds solutions of a certain partial differential equation of mixed type which is said to arise in elasticity theory.

George F. Carrier, USA

3124. Roma, M. S., On the numerical solution of systems of linear algebraic equations by the method of orthogonalization (in Italian), *Ric. sci.* **20,** 8–9, 1288–1290, Aug.-Sept. 1950.

Purpose of paper is to clarify the final result obtained for

numerical solution of a system of linear algebraic equations by the so-called orthogonalization method. Some objections to this method were made on the basis of the large number of operations it demanded. Author answers that it has the advantage of good accuracy and avoids the errors of computing fatigue.

Maria Castellani, USA

3125. **van Heemert, A., A generalization of the formula of Parseval,** *Nat. LuchtLab. Amsterdam Rap.* F 38, Sept. 1948, published 1951.

Author discusses evaluation of the definite integral of the product of two functions f and g, when the integral is improper and the principal value in Cauchy sense is required. For f and g "well behaved," Parseval's theorem gives the integral in terms of a sum involving Fourier coefficients of f and g. He shows that generalized Parseval's theorem still holds for certain restrictions, mainly (1) principal value of integral of g exists, (2) f has a finite number of jump discontinuities. Such integrals occur in airfoil theory.

C. C. Gotlieb, Canada

3126. **Sato, Y., Transformations of wave functions related to the transformations of coordinates systems. I,** *Bull. Earthq. Res. Inst. Tokyo Univ.* **28,** parts 1–2, 1–22, Jan.-June 1950.

On solving boundary-value problems of the wave equation, solutions are often sought in specified coordinates system such that one of the coordinates is constant on the boundary surface. For facilitating such computations, author deals with transformation of wave functions in two- and three-dimensional space. In two dimensions he transforms the cylindrical wave $H_m^{(2)}(kr)\exp(im\theta)$ (time factor $\exp(ipt)$ is omitted throughout) by Fourier's double integral theorem from polar to Cartesian coordinates and finds results in form of a definite integral which is identical for $m = 0$ with that obtained by H. Lamb [*Phil. Mag.* 203, 1, 1904] and H. Nakano [*Jap. J. Astro. Geophys.* 2, 1, 1905]. This transformation is useful if boundary surfaces are circular cylinder and infinite plane. If they are formed by two eccentric circular cylinders, it is useful to translate the origin of polar coordinates. Performing it on the deduced formula, author gets an infinite series known as Gegenbauer's addition theorem of Bessel functions. He gives also a trivial formula for rotation of polar coordinates, so any coordinates transformation of a cylindrical wave can be carried out. In three dimensions he transforms spherical wave $(kR)^{-1/2}H^{(2)}_{n+1/2}(kR)\,P_n^{-m}(\cos\theta)\times\exp(+im\varphi)$ by Fourier's double integral theorem from polar to Cartesian coordinates and obtains result in form of a double definite integral which is identical with that computed by S. Syono [*Geophys. Mag.* 12, 67, 1934] by Weyl's transformation. This transformation is used to get solutions of wave equation satisfying conditions given on both spherical and plane surfaces. For expressing a spherical wave by means of cylindrical waves, he transforms it with the help of Hankel's double integral theorem from polar to cylindrical coordinates and finds result in form of a definite integral which has been obtained for $m = n = 0$ by H. Lamb in the above-mentioned paper. For solving problems of wave propagation from a point within a spherical body or scattering of spherical waves by a spherical body, the origin of polar coordinates is translated. Using result of the previous transformation, author finds, after certain reductions, that a general spherical wave written in spherical coordinates can be expressed in terms of a different origin by the sum of the same kind of wave functions whose orders n are not smaller than m, while their degree m is invariably the same as that of given wave function. Paper also shows relations between transformations due to Fourier, Weyl, and Hankel. Reviewer believes that its value would be increased if author included some examples on how to use the deduced transformations for solving given boundary-value problems.

Jaroslav Pachner, Czechoslovakia

3127. **Friedman, M. D., Determination of eigenvalues using a generalized Laplace transform,** *J. appl. Phys.* **21,** 12, 1333–1337, Dec. 1950.

A general method for determining eigenvalues of second-order differential equations is obtained through the use of the Laplace transform. This method, as is characteristic of the operational calculus, provides a semi-automatic means of obtaining eigenvalues; method described is in some instances less laborious than so-called classical methods. Special cases of the Sturm-Liouville equation, including the Bessel, Hermite, Laguerre, Legendre, Jacobi, Tschebyscheff, and trigonometric equations, are discussed. The interval of integration defining the Laplace transform is different for each equation. Because the method which is expounded offers no new insight to the nature of the eigenvalue problem, it is quite unlikely that this method will replace (even to a small extent) the well-known Sommerfeld polynomial method, especially in quantum mechanics.

Lawrence Baylor Robinson, USA

3128. **American Society of Mechanical Engineers, Ten-year index to ASME technical papers,** New York, Amer. Soc. mech. Engrs., 1951. $5.

Book is an index to the more than 2000 papers published in the ASME Transactions, the *Journal of Applied Mechanics*, and MECHANICAL ENGINEERING from January 1940 to December 1949. There are two listings: a 4800-item subject index with numerous cross references, and an alphabetically arranged author index with reference to the subject under which complete information on a paper in question can be found. Ed.

3129. **Lee, Y. W., Communication applications of correlation analysis,** *Symp. appl. Autocorr. Anal. Phys. Probl.*, pp. 4–23, 1949.

Author stresses contrast between classical communication theory (concerned with functions of periodic or transient character completely specified for a [illegible] time) and recent statistical communication theory concerned, like the theory of noise, with stationary random processes. For this paper the first two distribution densities, namely amplitude and joint distribution, suffice. Special study is made of the autocorrelation function based on systematic sampling, aimed at detecting weak periodic signals largely masked by observed noise. The theory of design of optimum filters and predictors is based on Norbert Wiener's work. Actual examination of sample records has served to confirm the statistical prediction theory and to indicate further practical applications.

Albert A. Bennett, USA

Mechanics (Dynamics, Statics, Kinematics)

(See also Rev. 3120)

3130. **Tölke, F., Mechanics of deformable bodies, I. Particles (Mechanik deformierbarer Körper, I. Der punkformige Körper),** Berlin, Springer-Verlag, 1949, viii + 388 pp. DM 45.

Author has set himself the somewhat risky task of supplementing the literature about mechanics, numerous though it is, by a new series of books regarding mechanics of deformable bodies. Evidently, such a series should cover almost the entire field of mechanics. It is intended to be adapted chiefly to technical applications and to discuss problems raised by the development of engineering, especially those of mechanical engineering. The following division is planned: Vol. I: The punctiform body. Vol. II:

The solid body under static strain. Vol. III: The solid body under dynamic strain. Vol. IV: The solid body under thermic strain. Vol. V: Liquids and gases. Vol. I has been published.

In spite of its restrictive title, material systems (accumulations of points) are treated in following chapters: Motion along a straight line of a body considered as a material point; vectorial, geometrical, and kinematical principles; mechanical principles; motions in central potential fields; mechanics of motions in space and relative motions; mass center of a system of material points; mechanics of a system of material points; coupled harmonic vibrations together with forced vibrations; damped vibrations. The general principles of mechanics, such as Newton's axioms and the kinematic definitions connected with them, are treated in full detail. In addition, author gives a comparatively detailed synopsis of mathematical principles, especially those of vectorial mathematics. This causes the contents of this book to overlap with others in the special literature field, an impression enhanced by the rather too abstract title of the book and the chapter headings.

Though dynamics of systems of material points is treated in a rather extensive manner, Lagrange's equations and Hamilton's theory are missing, both of which would often have abbreviated and facilitated the treatment of this subject to a great extent. However, the book contains quite a number of technically interesting examples (55 altogether) suggestive to the student and offering new aspects even to the specialist. Owing to its high price there is little chance of its being accessible to many readers. It is indeed still a matter for discussion whether, in view of the special literature already existing, there is justification for printing voluminous books such as these, or whether the writing of standard works should not in the future be undertaken as the teamwork of several specialists who are in a position to adapt the contents to the various requirements of the engineer, in which case at least all technical libraries would be ready to buy them. Finally, a better title would have made it easier to sell this book.

H. Neuber, Germany

3131. Käppler, P., Dynamics of the type-lever mechanism in a typewriter (in German), *Z. Ver. dtsch. Ing.* **93,** 9, 209–214, Mar. 1951.

A mathematical study is combined with experimental determination of the action of the hand and finger on the key to determine the optimum lever ratios for speed of typing. Curves are given for the motions, velocities, and forces during the printing stroke and the return stroke of the customary five-element typing mechanism and for a six-element variation known as the Wagner mechanism. Michael Goldberg, USA

3132. Altmann, F. G., On the number synthesis of spatial coupled mechanisms (in German), *Z. Ver. dtsch. Ing.* **93,** 9, 205–208, Mar. 1951.

Author considers linkage systems which are equivalent to kinematical chains with four members, each having two coupling points. In particular, he presents several examples of systems which transform motion of rotation into rotation, translation, or oscillation by means of couplings comprised only of cylindrical shafts and bearings. The relation of the paper to a general "number synthesis" is not clear to the reviewer.

Phillip Eisenberg, USA

3133. Bowden, F. P., Friction, *Nature* **166,** 4217, 330–334, Aug. 1950.

Author reviews "laws" of friction and shows that measurements of real contact area explain these laws. Real area of contact is directly proportional to applied load and is independent of surface size. High local pressures at points of contact cause plastic flow of surface material. Adhesion, therefore, takes place and is the primary cause of friction. Experiments show that coefficient of adhesion (ratio of normal force required to separate surfaces to the applied normal load) for soft materials with little elastic recovery is approximately equal to coefficient of friction. Surface films of any type decrease friction markedly.

Measurement of surface temperature of sliding solids, by use of the surfaces themselves as elements of a thermocouple, shows that instantaneous temperatures in order of 500–1000 C are attained. These local hot spots explain polishing or formation of Beilbey layer.

Teflon shows low (0.04) friction coefficient even at 300 C and therefore appears promising. Sintered copper impregnated at surface with Teflon also showed low (0.05) friction coefficient to 250 C. E. E. Bisson, USA

3134. Nagasu, H., Statistical features in static friction, *J. phys. Soc. Japan* **6,** 2, 123–124, Mar.-Apr. 1951.

Static friction or, more precisely, tangential breakaway load was measured on plane surfaces, both of them made of steel and solvent-cleaned. Normal load was kept constant throughout, and three rates of tangential loading were applied. Breakaway force, as usual, showed considerable scatter, and its most frequently occurring value was found to increase distinctly with an increase in rate of tangential loading. Supplementary study along the lines followed by Parker and Hatch [AMR **4,** Rev. 1181] might well disclose the basic cause of the scatter observed.

H. Blok, Holland

3135. Weibel, E. E., Elasticity and friction in toggle systems, *Proc. Soc. exp. Stress Anal.* **8,** 2, 229–238, 1951.

Paper discusses the condition for stable and unstable operation of toggle mechanisms by considering both the elastic properties of the elements composing the applied and resisting forces of the toggle, as well as the frictional forces acting on these elements. Analysis is made for each of these conditions separately and then combined into a useful result which is presented both analytically and graphically. It seems probable that the high forces in toggle systems may be predicted with accuracy on the basis of computed values of elastic constants and of assumed frictional coefficients.

F. L. Singer, USA

3136. Levy, S., and Kroll, W. D., Response of accelerometers to transient accelerations, *J. Res. nat. Bur. Stnds.* **45,** 4, 303–309, Oct. 1950.

Numerical integration is used to determine response of twelve ideal seismic accelerometers to square, triangular, and half sine pulses of equal duration. The natural periods of accelerometers selected are one, one-third, and one-fifth of the pulse duration, each with damping coefficients of 0, 0.4, 0.7, and 1.0 times critical. Of primary interest are the nine figures showing the response of the instruments to the selected pulses. Brief discussion. Response errors are tabulated. No observed case of errorless response is given. Response error is reduced by time shift of response curve. Magnitude of time shift for reduced error in each case is tabulated (all different) but not discussed. G. R. Carlson, USA

3137. Tzenoff, Iv., Some new forms of the general equations of motion of material systems (in Bulgarian), *Godishnik Univ. Sofia* **1,** 45, 239–261, 1949.

Consider a nonholonomic system, and let $k + p$ be the number of independent coordinates q_α, $q_{\alpha+i}$ ($\alpha = 1, 2, \ldots, k$; $i = 1, 2, \ldots, p$) required to specify the configuration of the system, and k be the number of its degrees of freedom. Suppose that

$$q'_{k+i} = \Sigma_\alpha a_{i\alpha} q'_\alpha + a_i \quad (i = 1, 2, \ldots, p) \qquad [1]$$

are the nonintegrable equations connecting the variations of the coordinates; in holonomic systems these equations are of course nonexistent. The kinetic energy T_0 of the system, not taking into account [1], i.e., the kinetic energy of the associated holonomic system, is a function of $t, q_\alpha, q_{\alpha+i}, q'_\alpha, q'_{\alpha+i}$, and its first- and second-order derivatives T'_0 and T''_0 with respect to t involve the derivatives of q_α and $q_{\alpha+i}$ up to the second and third orders, respectively. The kinetic energy T of the nonholonomic system and the derivatives T' and T'' are obtained from T_0, T'_0 and T''_0, respectively, by taking into account [1].

Denote by T'_1 and T'_2, respectively, the function T'_0, considered as a function of the q'_α, q'_{k+i}, and of the q''_α, q''_{k+i}, respectively, the derivatives q'_{k+i} and q''_{k+i} being given by [1] and the relation obtained from it by differentiation with respect to t. Similarly denote by T''_2 and T''_3, respectively, the function T''_0, considered as a function of the q''_α, q''_{k+i} and the q'''_α, q'''_{k+i}, respectively.

The author obtains the following three novel forms for the equations of motion of a nonholonomic system:

$$2(d/dt)(\partial T/\partial q'_\alpha - \partial T'/\partial q'_\alpha + 3\,\partial T'_2/\partial q'_\alpha - 2\,\partial T''_3/\partial q''_\alpha = Q_\alpha,$$
$$2\,\partial T''/\partial q''_\alpha - 3\,\partial T'/\partial q'_\alpha + 3\,\partial T'_2/\partial q'_\alpha - 2\,\partial T''_3/\partial q''_\alpha = Q_\alpha,$$
$$2\,\partial T''_2/\partial q''_\alpha - 3\,\partial T'_1/\partial q'_\alpha = Q_\alpha \qquad (\alpha = 1, 2, \ldots, k),$$

which become considerably simpler in the holonomic case. The first set of equations may also be put in Lagrange's form, if one introduces on the left-hand side of these equations a supplementary term whose expression can be easily deduced.

Further, assuming that the derivatives q'_α are linear functions of new variables ω_β, some transformed forms for the equations of motion of both nonholonomic and holonomic systems are obtained.

These new equations of motion are applied to the motion of a hoop on a fixed horizontal plane. Two cases are considered: (1) the hoop slides without friction, and (2) it rolls without sliding.

E. Leimanis, Canada

Gyroscopics, Governors, Servos

(See also Rev. 3146)

3138. Andronov, A., and Maïer, A., Vyshnegradskiĭ's problem in the theory of direct regulation. I. The theory of the regulator of direct action in the presence of Coulomb and viscous friction (in Russian), *Avtomatika i Telemekhanika* **8**, 314–334, 1947.

The dynamics of Watt's governor is one of the oldest and most extensively studied problems in the theory of automatic control mechanisms. Authors present the first part of a careful analytic treatment of the direct centrifugal regulator (driven without servomotor) under the usual simplifying assumptions in the presence of Coulomb and viscous friction. The equations going back to Vyshnegradskiĭ [*C. R. Acad. Sci. Paris* **83**, 318–321, 1876] are $d^2x/dt^2 + Bdx/dt + Ax = y \mp \frac{1}{2}$, $dy/dt = -x$. The portrait of the corresponding phase space for various values of the parameters is analyzed by the classical methods of Lyapunov and Poincaré.

Courtesy of Mathematical Reviews M. Golomb, USA

3139. Meerov, M. V., On systems of autoregulation stabilized for an arbitrarily large coefficient of amplification (in Russian), *Avtomatika i Telemekhanika* **8**, 225–242, 1947.

A general method is considered for the synthesis of linear control mechanisms which are to be stabilized for arbitrarily large amplification coefficients by the use of a prescribed type of stabilizing loops. Obtained are general rules for connecting a stabilizing loop of the prescribed type, the rules depending on the number of elementary links in the system. They are derived from conditions under which the polynomial $P_1(p) + mP_2(p)$ is stable (that is, all its zeros have negative real part) for all sufficiently small m, when it is known that $P_1(P)$ is a stable polynomial.

Courtesy of Mathematical Reviews M. Golomb, USA

3140. Gol′dfarb, L. S., On some nonlinearities in systems of regulation (in Russian), *Avtomatika i Telemekhanika* **8**, 349–383, 1947.

Self-oscillations in automatic control systems containing various nonlinear elements, their frequencies, amplitudes, and stability are determined by the method of approximative "harmonic balance." The approximation is of the first order, being essentially the well-known method of "linearization" [see, e.g., Kryloff-Bogolyubov, "Introduction to nonlinear mechanics," Princeton University Press, 1943]. Numerous concrete regulating schemes are treated.

Courtesy of Mathematical Reviews M. Golomb, USA

3141. Bulgakov, B. V., Regulation chains with links having several degrees of freedom (in Russian), *Prikl. Mat. Mekh.* **14**, 6, 619–634, Nov.-Dec. 1950.

The regulating circuits discussed are constructed from units connected together in a circle. The units are governed by linear differential equations with constant coefficients. Applications are made to problems involving a ship-steering mechanism and a gyroscopic stabilizer.

Courtesy of Mathematical Reviews F. N. Gilbert

Vibrations, Balancing

(See also Revs. 3118, 3225)

3142. Felgar, R. P., Formulas for integrals containing characteristic functions of a vibrating beam, *Univ. Texas Bur. Engng. Res. Circ.* 14, 55 pp., 1950.

3143. Mendelson, A., and Gendler, S., Analytical and experimental investigation of effect of twist on vibrations of cantilever beams, *Nat. adv. Comm. Aero. tech. Note* 2300, 48 pp., Mar. 1951.

Authors develop the general equations for the coupled bending-bending-torsion vibrations of a cantilever beam, typical of a compressor or turbine blade, by the use of station functions, a concept introduced by Rauscher [AMR **3**, Rev. 1762]. Tabulated station numbers are presented to simplify the analytical method.

Method is illustrated by determining the natural frequencies of the coupled bending-bending modes of cantilever beams, having linear twist, with total angle of twist ranging from 0 radians to 1.0 radian. It is shown that for a beam with a ratio of bending stiffness in the two principal directions of the cross section equal to 144, the effect of coupling due to twist is to raise the value of the first natural frequency by a negligibly small amount, to decrease steadily the second frequency, and to lower the third frequency considerably. The approximate method presented has good agreement with an exact theoretical solution developed by author and with experiment results. T. H. H. Pian, USA

3144. Lurie, H., Vibrations of rectangular plates, *J. aero. Sci.* **18**, 2, 139–140, Feb. 1951.

Author points out the fact that problem of vibration of a

rectangular plate is similar to that of buckling, so available buckling data may be used to solve some vibration problems. For the case of two opposite edges simply supported and the other two edges arbitrarily supported, he gives the natural frequencies in terms of the plate buckling factor k.

N. O. Myklestad, USA

3145. Kohn, P., Relation between operating and critical speeds of multistage centrifugal pumps, *Engng. Rev. Prague* no. 5, 1–5, Oct. 1950.

Effect of unbalance on the deflection of a rotating shaft of uniform diameter is considered. Unbalance is assumed to be all in one radial plane but arbitrarily distributed along the span. Unbalance distribution is expressed by a Fourier series, and an expression for the deflection is obtained in terms of the critical speeds and the Fourier coefficients.

It is shown that infinite deflections occur for odd-order critical speeds if the unbalance is static only, while for dynamic unbalance, deflections are infinite for even-order critical speeds.

Limits are set up for safe operation in the region of the second critical speed based on limits in the region of the first critical speed which have been satisfactory in practice. Three different criteria are used in determining the limits. These are maximum shaft deflection, maximum shaft slope at bearings, and maximum dynamic bearing pressure. For the last two, satisfactory operation above the second critical is found to be not possible.

W. O. Richmond, Canada

3146. Sokolov, V. I., Critical velocities of ultracentrifuges, *Nat. adv. Comm. Aero. tech. Memo.* 1272, 11 pp., Mar. 1951.

Critical speed of a rigid rotor on a massless flexible spindle is obtained. Two methods of passing through critical speed are discussed: rapid acceleration, and the use of restricting rings which limit the amount of bending of the spindle.

Stephen H. Crandall, USA

3147. Bennett, G. S., On multiple excitation of an elastic system, *J. acoust. Soc. Amer.* **23,** 2, 229–231, Mar. 1951.

This brief note reviews the steady-state response of a mechanical oscillation to multiple frequencies. Conclusion of interest is that, while systems with certain types of nonlinear springs and dampers give rise to beat frequencies, the resonance amplitudes under these beat frequencies do not appear to be appreciable. Experiments confirm the conclusion. C. Richard Soderberg, USA

3148. Plunkett, R., Free and forced vibrations of rotating blades, *J. aero. Sci.* **18,** 4, 278–282, Apr. 1951.

This paper analyzes the free and forced vibrations of rotating airplane propellers or turbine blades by writing their dynamical equations in matrix notation. By an iterative process the variation of the natural frequencies of these systems with the angular velocity of rotation is determined. A similar procedure is used to find the forced vibrations caused by oscillatory loading. In reviewer's opinion, the method presented has some computational advantages over the Rayleigh and Myklestad methods.

Louis A. Pipes, USA

3149. Cecconi, J., On a differential equation for relaxations (in Italian), *Atti Accad. Naz. Lincei Rend. Cl. Sci. Fis. Mat. Nat.* (8), **9,** 1–2, 38–44, 1950.

Author studies the equation $y'' + y'|y'| - qy' + y(1 - p^2y^2) = 0$ with damping which is partly negative ($-qy'$ and half of the cycle $y'|y'|$) and partly positive (the other half of the $y'|y'|$ cycle). Also the spring constant $1 - p^2y^2$ becomes negative for large values of the parameter p. Paper shows that a periodic solution exists for sufficiently small values of p. A hodograph diagram of the solution is given. J. P. Den Hartog, USA

3150. Vogel, A., Calculation of torsional natural vibrations of machine shafts (in German), *Z. angew. Math. Mech.* **30,** 11/12, 363–369, Nov.-Dec. 1950.

Author sets up a dynamical matrix whose characteristic values are squares of natural frequencies of torsional system of lumped masses and shafts. He shows how the dynamical matrix can be replaced by a symmetrical matrix or by a matrix with non-negative elements. For homogeneous machines (masses of equal polar moment, shafts of equal torsional stiffness per unit length) natural frequencies are known [e.g., Kármán and Biot, "Mathematical methods in engineering," McGraw-Hill, N. Y., 454–459, 1940]. For partly homogeneous machines with a few additional masses, method of Grammel conveniently determines natural frequencies from tabulated frequency functions. For inhomogeneous machines, iteration procedure for determining greatest root of a matrix can be adapted to find lower natural frequencies. Author illustrates last with a numerical example.

Reviewer is reasonably certain that methods discussed are familiar to those acquainted with matrix algebra.

Herman A. Lang, USA

Wave Motion, Impact

(See also Revs. 3126, 3403)

3151. Seth, B. R., Some solutions of the wave equation, *Proc. Indian Acad. Sci. Sec. A,* **32,** 6, 421–423, Dec. 1950.

The two-dimensional wave equation $\partial^2\phi/\partial x^2 + \partial^2\phi/\partial y^2 = c^2(\partial^2\phi/\partial t^2)$ with the boundary condition $\phi = k\cos(pt/c)$, k constant, occurs, according to the author, in the theory of the bending of plates. Solutions are given in series for the rectangle and the isosceles right-angled triangle; and in closed form for the equilateral triangle. There are many misprints.

Fritz Joseph Ursell, England

3152. Ladízhenskaya, O., On the Fourier method for the wave equation (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **75,** 6, 765–768, Dec. 1950.

The sufficient conditions given previously by author (no reference listed) for termwise double differentiation of a Fourier series are relaxed in the case of a sufficiently smooth boundary condition so that the existence of the same number is required as for the corresponding Cauchy problem. Method is applied to an n-dimensional wave equation whose solution u vanishes on the boundary, and also to one in which the solution satisfies the equation $\partial u/\partial n + h(s)u = 0$ on the boundaries.

R. T. Beyer, USA

3153. Denny, D. F., Further experiments on wave pressures, *J. Instn. civ. Engrs.* no. 4, 330–345, Feb. 1951.

Exhaustive experimental investigation of the pressures exerted by 7-, 12-, and 14-in. waves breaking against a vertical wall. Results support the theory published in 1939, by Bagnold, showing that an air pocket plays a dominant part in the generation of shock pressures. Statistical analysis shows that the pressures are substantially proportional to wave height, and are greatest over the upper four tenths of the wave height. The product of pressure and duration approaches a constant proportion (0.466) of the initial momentum of the wave. Intense shocks last in the order of 0.001 sec. Scaling-up of the model results appears to be successful and is of much interest. E. G. Fischer, USA

3154. **Miller, R. W., and Merten, K. F., Comparison of theoretical and experimental response of a single-mode elastic system in hydrodynamic impact,** *Nat. adv. Comm. Aero. tech. Note* 2343, 26 pp., Apr. 1951.

Hydrodynamic impact tests were made on an elastic model approximating a two-mass spring system to determine experimentally the effects of structural flexibility on the hydrodynamic loads encountered during seaplane landing impacts and to correlate the results with theory. A flexible seaplane was represented by a two-mass spring system consisting of a rigid prismatic float connected to a rigid upper mass by an elastic structure. The model had a ratio of spring mass to hull mass of 0.6 and a natural frequency of 3.0 cps. The tests were conducted in smooth water at fixed trims and included both high and low flight-path angles and a range of velocity.

Results of the tests are compared with theoretical time histories of hydrodynamic impact force and elastic-system response calculated by the method in *NACA T.N.* 1398, which considers the applied hydrodynamic load and structural response to be interdependent or coupled throughout the impact. The hydrodynamic-force time histories obtained with the elastic system are also compared with the hydrodynamic-force time histories that would have been obtained for the same initial conditions if the system were rigid. These comparisons indicate that the theoretical results agree well with the experimental results.

From authors' summary

3155. **Taylor, J. L., Impact on beams and plates,** *Bull. tech. Univ. Istanbul* **2,** 2, 17–26, 1949.

Author professes to derive the vibrational equations for rods and plates when the rotational inertia and shearing deflection are taken into consideration. His derivation does not seem to be correct. Rayleigh has obtained the corresponding differential equation ["Theory of sound," Article 186]. Author seems to attach two different meanings to the displacement component v, and thus gets an equation different from that of Rayleigh. He also does not consider the correction due to the distortion of cross sections in their planes, which is as important as that due to rotational inertia. The corresponding changes to be made in the terminal conditions are also not mentioned.

There is a misprint in the formula in line 10 on page 20. It should be $(PA/g)\partial^2(u + v)/\partial t^2$, and not $(PA/g)\partial^2 u/\partial t^2$.

B. R. Seth, India

3156. **Peters, A. S., The effect of a floating mat on water waves,** *Comm. pure appl. Math.* **3,** 4, 319–354, Dec. 1950.

Paper presents a mathematical discussion of the progression of waves (on infinite depth) under a *thin* cohesionless mat of floating heavy bodies, e.g., broken ice. It seems that no direct practical applications can be made of the *general* solution (see below).

Mathematically, the problem discussed is that of finding harmonic functions in the half plane $y \leqq 0$, where the boundary condition for positive x (free-water surface) differs from that for negative x (mat-covered surface). The problem is solved by an ingenious analysis of conformal mapping and, indeed, not only for the half plane, but also for a wedge-shaped sector of arbitrary angle and with different boundary conditions along the two sides. Thus, the general solution includes those of (non-breaking!) surface waves over sloping beaches and of waves under a floating dock (= mat rigid). These problems were also solved by Isaacson and Friedrichs-Lewy.

As a result, author states that the waves cannot progress to any great distance inside the mat if the mass of the mat exceeds that of water of a depth $L/2\pi$, where L is the wave length of the oncoming waves. For a lighter mat, progressing waves are found under the mat (with an altered wave length and amplitude).

Reviewer believes that, like several recent mathematical papers on the reflection of waves, analysis in this paper idealizes the problem to the extent of neglecting important physical features. Thus, the mat will displace an equivalent mass of water that cannot be neglected. Physically, it seems that a light mat might have very little effect on the waves (neglecting internal friction in the mat), whereas a mat comparable with L would give great reflection from the front. H. Lundgren, Denmark

3157. **Morison, J. R., The effect of wave steepness on wave velocity,** *Trans. Amer. geophys. Un.* **32,** 2, 201–206, Apr. 1951.

Theoretical equations are presented for the effect of wave steepness on wave velocity. Experimental data are presented to show that, for practical purposes, this effect can be neglected.

From author's summary

3158. **Takahashi, T., and Satô, Y., On the theory of elastic waves in granular substance. II,** *Bull. Earthq. Res. Inst. Tokyo Univ.* **28,** parts 1–2, 37–43, Jan.-June 1950.

In a previous paper (see AMR **4,** Rev. 2374), authors investigated theoretically the velocity of elastic waves in sand. They conceived a three-dimensional space containing packed elastic spheres as a model. Each sphere was assumed to be anisotropic, but statistically the substance was considered to be isotropic on the macroscopic level. In the present paper, authors investigate the local aeolotropic nature of the substance and determine velocities of waves for simple cubic, body-centered cubic, and face-centered cubic crystalline types.

Over half of this short paper is concerned with the details of decomposing a symmetric tensor used in the first paper.

W. H. Hoppmann, II, USA

3159. **Reĭnov, M. N., On the calculation of the velocity potential of the motion of a fluid, caused by displacement of an immersed body** (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **77,** 2, 201–204, Mar. 1951.

A general solution for the wave motion generated by a horizontal uniform translation of a body in the neighborhood of a free surface has been given by Kochin. Purpose of present paper is to reduce the large amount of computations involved by tabulating auxiliary functions. General expansions and asymptotic representations are given. Georg P. Weinblum, USA

Elasticity Theory

(See also Revs. 3123, 3174, 3175, 3178, 3182, 3187)

3160. **Stakgold, I., The Cauchy relations in a molecular theory of elasticity,** *Quart. appl. Math.* **8,** 2, 169–186, July 1950.

The potential energy of the volume element of an elastically deformed body (the elastic potential) can be written

$$\Phi = \Phi_0 + \Omega^{ij}e_{ij} + \Lambda^{ij,kk}e_{ij}e_{kk} + \cdots.$$

However, when the initial external forces equal zero, the absolute term vanishes and so does the linear term in the deformation component (e_{ij}). Thus, there remains only the quadratic term with its 81 tensor components $\Lambda^{ij,kk}$. On the other hand, from the definition of the deformation components it follows that they reduce to 36, and from the existence of the elastic potential follows a further reduction to 21. Cauchy has shown that, when only central forces are acting between the molecules, one can establish another six relations between the components. Paper discusses

the necessary and sufficient conditions for the validity of the Cauchy relations. For a monatomic lattice, the idea of Voigt and Born is carried out strictly mathematically, introducing only the assumption that small regions exist in which the deformation can be considered as homogeneous, these nevertheless being large compared with the distance of molecular interaction. A discussion is given of the fact that, for multiatomic lattices, as already established by Born, the Cauchy relations are no longer valid, even in the case of central forces.

Courtesy of Mathematical Reviews T. Neugebauer, Hungary

3161. Rothman, M., Isolated force problems in two-dimensional elasticity II, *Quart. J. Mech. appl. Math.* **3,** part 4, 469–480, Dec. 1950.

Article is part II of the application of Stevenson's complex potential method to the analysis of plane stress problems. (Part I: AMR **4,** Rev. 1034.) Solutions are obtained for the circular disk and curvilinear disk under isolated boundary forces. For certain values of the parameters the curvilinear disks can be made to resemble the standard cement testing briquette or a shallow-tooth gear. John E. Duberg, USA

3162. Filin, A. P., On a consequence of a variational principle of the theory of elasticity (in Russian), *Prikl. Mat. Mekh.* **14,** 451–452, 1950.

It is shown that the principle of minimum complementary energy (Castigliano's principle) also represents the continuity condition for an arbitrarily stressed body.

Courtesy of Mathematical Reviews H. I. Ansoff, USA

3163. Berti, G., Saint-Venant's problem in hereditary elasticity (in Italian), *Boll. Un. mat. ital.* (3), **5,** 139–144, 1950.

Author applies Volterra's accumulative theory of elasticity to the deformation to straight bars loaded at their ends. Closely guided by Saint-Venant's results in the classical theory, she obtains solutions for extension, bending by a terminal couple parallel to a principal axis of inertia of the section, and torsion. The displacements are of Saint-Venant's type except for a multiplicative function of time. The results are presented in terms of operators defined by means of Volterra's coefficients of accumulation and of the inverses of these operators (not shown to exist).

C. Truesdell, USA

3164. Tekinalp, B., On the compression of a cube between rough end-blocks, *Bull. tech. Univ. Istanbul* **2,** 2, 101–110, 1949.

Author applies the hypercircle method developed by W. Prager and J. L. Synge [AMR **1,** Rev. 39] to obtain the average Young's modulus of a cube compressed between two rough planes coinciding with two opposite surfaces of the cube.

A. Cemal Eringen, USA

3165. Pailloux H., Remarks concerning the Castigliano theorem (in French) *C. R. Acad. Sci. Paris* **232,** 11, 1062–1064, Mar. 1951.

Author extends Castigliano theorem to case where loading is distributed continuously, and applies extended theorem to vibrations of a straight beam and of a rigid shaft.

From author's summary by Roy C. T. Smith, Australia

3166. Petersen, C., The practical determination of stress concentration factors in notched bars (in German), *Forsch. Geb. Ing.-Wes. Ausg. B.* **17,** 1, 16–20, 1951.

In 1937, Neuber established a firm theoretical foundation for treatment of notch stresses. Because of complexity of the relations, a chart was prepared for determination of numerical values of stress-concentration factor. On the basis of careful experiments at Darmstadt, present author, although retaining general theory, proposes a simpler formula agreeing more closely with test data. New formula can also be presented as a nomogram and is believed particularly useful in design of shafts of varying diameter, with fillets at changes of section, subjected to bending or torsion. C. W. Smith, USA

3167. Fine, M., and Pellew, A., A method of estimating the direct stress concentration round holes in reinforced sheet, *Aero. Res. Counc. Lond. Rep. Mem.* 2604, 6 pp., May 1942, published 1951.

Method is based on stringer-sheet solution for uniform flat sheet reinforced on longitudinal edges by heavy flanges. Skin is assumed to take shear only, while stringer sheet, which includes allowance for flanges, takes only direct stress. Equation for longitudinal equilibrium in terms of displacement can be transformed to Laplace's equation so that analogies may be used to determine stress distribution. Transverse equilibrium is not satisfied.

Results are worked out for elliptical hole in uniform sheet in tension field with error of order of 20% when compared with exact solution. Method is useful only as guide to stress distribution.

W. O. Richmond, Canada

3168. Durelli, A. J., and Jacobson, R. H., On stress concentration factors produced by deep notches of small radius of curvature (in Spanish), *Cienc. y Tecn.* **115,** 582, 373–381, Dec. 1950.

See Rev. 3175 in this issue.

3169. Lodge, A. S., The compatibility conditions for large strains, *Quart. J. Mech. appl. Math.* **4,** part 1, 85–93, Mar. 1951.

Author proves the sufficiency of six compatibility conditions for large strains obtained earlier by Weissenberg (not yet published). He also proves that a given strain field, applied to an initial configuration, determines the final configuration uniquely save for a rigid body displacement. D. N. Mitra, India

Experimental Stress Analysis

(See also Rev. 3168)

3170. Föppl, L., and Mönch, E., Practical photoelasticity (Praktische Spannungsoptik), Berlin-Göttingen-Heidelberg, Springer-Verlag, 1950, vii + 162 pp. DM 21.

Book presents the methods and experiences of the leading German photoelastic laboratory at Technische Hochschule in Munich. The elastical and optical foundations of photoelasticity are described briefly, as sufficient material on this subject may be found in other books (e.g., M. M. Frocht). For the same reason, optical equipment is only lightly touched upon. Authors strongly recommend use of polarization plates in connection with a long-distance lens camera as the simplest, most convenient, and cheapest equipment.

Mechanical and thermal treatment of photoelastic material, however, is thoroughly discussed. As is well known, authors have succeeded in developing a coating procedure by which the photoelastic models may be protected against loss of moisture during storage or heat treatment, thus avoiding the annoying "edge effect."

A broad treatment is also given to three-dimensional photoelasticity. Again, very precise data for the thermal treatment of the models are presented. Unfortunately, the ingenious method by Mindlin-Favre-Gilg [AMR **4,** Rev. 1487] is not mentioned in the section dealing with bending of plates.

The second part of book is concerned with special problems showing the broad field of applicability of photoelasticity.

The book will prove itself extremely useful to all practical photoelasticians. Printing is excellent.

Heinz Parkus, Austria

3171. **Vancrombrugge, R., Industrial apparatus for measuring static deformations** (in Dutch), *Tech. Wet. Tijdschr.* **20,** 4, 76–80, Apr. 1951.

Author deals with resistance variations and methods of measuring them. He examines the influence of cable resistance and capacity. He finally reviews a few instruments used to measure static deformations. From author's summary

3172. **Colle, J., Industrial equipment for measuring dynamic deformations** (in Dutch), *Tech. Wet. Tijdschr.* **20,** 4, 81–86, Apr. 1951.

Author deals with measurement of dynamic deformations by means of the strain gage. He describes various devices used for the purpose, then treats apparatuses which can register many different phenomena simultaneously. From author's summary

3173. **Wenk, E., Jr., A diaphragm-type gage for measuring low pressures in fluids,** *Proc. Soc. exp. Stress Anal.* **8,** 2, 90–96, 1951.

See AMR **3,** Rev. 2767.

3174. **Frocht, M. M., assisted by Landsberg, D., Factors of stress concentration in bars with deep sharp grooves and fillets in tension,** *Proc. Soc. exp. Stress Anal.* **8,** 2, 149–162, 1951.

Paper deals with photoelastic determination of stress concentration factors K for deep grooves and fillets in tension for very small ratios r/d (r is radius of fillet or groove, d minimum width of bar, D maximum width of bar). Tests covered range from r/d = 0.011 to 0.08 for $D/d = 1.5$ and $D/d = 2$. Results are also given showing effects of different methods of loading test specimens; i.e., through four pins; two outside pins; two inside pins; and by means of a friction grip. Estimate of error involved in determining K is made; for $r/d \leq 0.02$ author estimates probable range of error in K as 5 to 10%. A. M. Wahl, USA

3175. **Durelli, A. J., and Jacobson, R. H., Discussion of "Factors of stress concentration in bars with deep sharp grooves and fillets in tension,"** *Proc. Soc. exp. Stress Anal.* **8,** 2, 163–170, 1951.

Discussers summarize results of published investigations dealing with stress concentration factors for bars with grooves in tension. These investigations include theoretical analyses by Neuber and others; photoelastic investigations by Frocht; strain measurements by Preuss. It is concluded that Neuber's curves are best for design use. A. M. Wahl, USA

3176. **Ramachandran, G. N., and Chandrasekharan, V., Photoelastic constants of sodium chlorate,** *Nature* **167,** 4249, p. 567, Apr. 1951.

3177. **Stott, A. M., and McCaughey, J. M., Compression test extensometer for cylindrical specimens,** *Prod. Engng.* **22,** 4, 157–160, Apr. 1951.

An extensometer, developed for obtaining accurate stress-strain data when testing cylindrical specimens in compression, can be used for ferrous and nonferrous materials at temperatures ranging from —70 F to 400 F. Operator safety may be assured by remote operation of tests. From authors' summary

3178. **Tsien, L. C., and Ho, S. A., A new extensometer and some extensometric measurements on the anelasticity of aluminum,** *Sci. Rec. Peking,* **3,** 1, 67–76, Oct. 1950.

Paper describes a new extensometer for tensile tests on small specimens, 5 to 6 cm in length and 2 mm in diameter. Authors claim that the strain sensitivity is 2.6×10^{-7} cm. Some creep-recovery type tests on aluminum wires are reported and explained by considering residual stresses. Reviewer believes that range of extensometer deserves some consideration.

Ling-Wen Hu, USA

Rods, Beams, Shafts, Springs, Cables, etc.

(See also Revs. 3155, 3166, 3208, 3251)

3179. **Reissner, E., On the theory of beams on elastic foundations,** *Federhofer-Girkmann-Festschrift,* Wien, Franz Deuticke, 87–102, 1950.

The generalized problem of a beam of infinite length resting on an elastic foundation is reconsidered, and the general Fourier integral solution is discussed. In the case of a beam of finite length, problem can be reduced to an integral equation of the first kind for the foundation pressure and a method of solution of the integral equation is described. In the case of a three-dimensional elastic foundation, a suitable kernel function can be derived. Enrico Volterra, USA

3180. **Puchner, O., Fatigue strength of transversally bored shafts under combined statical and alternate bending and torsion stress** (in German), *Schweiz. Arch.* **17,** 2, 46–63, Feb. 1951.

Known solutions for stress distributions in an infinite plate with a hole, under uniform tension in one direction and uniform shear, are used as an approximation for the stress distribution in the neighborhood of a transversal boring in a shaft under bending or torsion. A relation between the statical and alternate normal and shear stresses and the maximum allowable stresses has been obtained, based on the theorem of Goodman. This is done for the cases when the alternate bending and torsion moments are in phase, and when they are not.

Calculations based on the derived formulas are compared with experimental results of the author and others; there is a reasonable agreement, provided that the ratio of bore-diameter and shaft-diameter $d/D < 0.1$ and that the average stresses are not too high.

Reviewer believes that the results obtained are important; however, a better approximation of the stress distribution and more experimental results are desirable.

J. W. Cohen, Holland

3181. **Allen, D. N. de G., and Sopwith, D. G., The stresses and strains in a partly plastic thick tube under internal pressure and end-load,** *Proc. roy. Soc. Lond. Ser. A,* **205,** 1080, 69–83, Jan. 1951.

Authors determine analytically the stresses and strains in a thick tube loaded so that yielding occurs. Their theory is one of total rather than incremental strain. Also, they assume constant stress difference and that the strains are independent of history of straining. Solutions are given in a form for practical application along with numerical illustrations. Comparison of results is made with the incremental solution of Hill, Lee, and Tupper with the disclosure that stresses calculated by the two theories differ by less than 5%. A brief review is also given of several other solutions to the problem which are in the literature of the subject. W. H. Hoppmann, II, USA

3182. Shepherd, W. M., On the stresses in close-coiled helical springs, *Quart. J. Mech. appl. Math.* **3,** part 4, 459–468, Dec. 1950.

Author deals with problem of torsion of an incomplete circular ring loaded by two opposite forces directed along axis of the ring. (This simulates stress conditions in helical springs axially loaded.) To solve problem, a stress function ϕ is used consisting of terms containing even powers of r and z which satisfy the differential equation (r and z are radial and axial coordinates of point of cross section of bar). Constants in function ϕ are so determined that $\phi = 0$ along a boundary approximating a circular shape (with sufficient accuracy for practical purposes). For practical ratios of coil-to-bar diameter, maximum torsional stresses obtained by this method agree closely with those obtained by Göhner using a somewhat different method [*Ing.-Arch*, p. 619, 1930; pp. 1 and 381, 1931]. Method is also applied to sections other than circular. Author investigates distortion of circular section due to coiling of spring wire using displacements obtained from equations for elastic bending and taking Poisson's ratio = 0.5. This analysis indicates practically negligible distortion for a circular section, but not for a square section, in agreement with actual measurements. A. W. Wahl, USA

3183. Torroja, E., Determination of stresses in straight beams, 2nd ed. (in Spanish), *Cons. Sup. Inv. Cien., Inst. tech. Constr. Cem. Madrid*, no. 100, 51 pp., 1950.

3184. Vedeler, G., Calculation of beams, *Trans. Instn. nav. Archit. Lond.* **92,** 1, 30–49, Jan. 1950.

Bending moments in beams and frameworks vary considerably with reference to the degree of rigidity of the end constraints. A method is set down for calculating both the degree of fixation and the influence of brackets on the bending moment. Diagrams are included for the calculation of the effective width of flanges. The methods developed not only include the author's deductions but also afford a good compilation of data from other sources pertinent to the determination of end restraints. The effect on the moments of beams or members of frameworks subjected to a constant compressive force and constant EI is shown.

Clarence B. Matthews, USA

Plates, Disks, Shells, Membranes

(See also Revs. 3151, 3155, 3213, 3222)

3185. Ōkubo, H., On the bending of thin aeolotropic plates, Reps. 1, 2, *Repts. Inst. high speed Mech., Tohōku Univ.* **2,** 10, 1–25 Mar. 1950.

The first report treats the bending problem of a thin circular or an elliptic plate subjected to uniform lateral load, where the edge is supported or clamped. Numerical calculations are carried out on wooden plates of several kinds. An empirical formula for the deflection is also introduced in a simple form, and its suitability for wooden plates is confirmed by comparing results calculated from the empirical formula with those of the exact solution.

In the second paper, the general solution for a rectangular plate with clamped edges, where the load is arbitrarily distributed over the surface of the plate, is introduced. Problem is solved in a way which permits solution of the following four fundamental cases, from which can be built up the general solution: (1) Load distributes symmetrically with respect to x and y axes. (2) Load distributes symmetrically with respect to x axis and antisymmetrically with respect to y axis. (3) Load distributes antisymmetrically with respect to x axis and symmetrically with respect to y axis. (4) Load distributes antisymmetrically with respect to x and y axes.

The empirical formula for the deflection, proposed by Grashof, is extended to the case of an aeolotropic square plate.

From author's summaries

3186. Chandra Das, S., Note on the bending of certain thin elastic plates by concentrated loads, *Bull. Calcutta math. Soc.* 42, 89–93, 1950.

Closed-form solutions are obtained for the transverse deflection of thin plates with clamped edge when the boundary of the plate is (1) the inverse of an ellipse, (2) an elliptic limaçon, and a concentrated load is acting at the origin and the focus of the limaçon, respectively. For the method of solution reference is made to B. Sen [*Indian Phys.-Math. J*, **5,** 17–20, 1934]. E. Reissner, USA

3187. Mitrinovitch, D. S., On an indeterminate differential equation occurring in an important problem of elasticity (in French), *C. R. Acad. Sci. Paris* **232,** 8, 681–683, Feb. 1951.

The problem of finding the extensional displacements in a thin shell of revolution unsymmetrically stressed is more difficult than that of finding the stress resultants. Apart from the classical results for the sphere and the cone, few if any exact solutions were known until the reviewer [*Trans. Amer. math. Soc.* **58,** 96–166, 1945, see § 18] reduced the problem to the integration of the single equation

$$\frac{F''}{F} - \left(\frac{f'''}{f''} + \frac{f'}{f}\right)\frac{F'}{F} + n^2\frac{f''}{f} = 0$$

$r = f(z)$ being the Cartesian equation of the shell meridian and n an integer. Although the reviewer obtained some special solutions [op. cit.; eqs. (20.2), (21.6), (21.8), (21.11), (21.13), (21.21), (22.8)], he did not give a systematic method of integration. Author constructs an inverse method whereby, starting from an arbitrary function, by means of two quadratures and two inversions of variables one may obtain simultaneously a meridian curve $r = f(z)$ and the solutions F belonging to it. As an example, he notes a special case obtained by the reviewer [op. cit., eq. (21.11)]. He then indicates how his method applies to a large class of differential equations. This idea is to be developed in a later study. C. A. Truesdell, USA

3188. Ono, A., On fracture of materials taking place on a plane parallel to the direction of thrust, *Memo. Fac. Engng. Kyushu Univ.* **11,** 4, 189–199, 1949.

Continuation of work on growth of cracks in brittle materials, along lines proposed by A. A. Griffith. Author assumes slender elliptic crack with long axis parallel to thrust; presents detailed analysis of elliptic hole; then deduces associated energy and work relations to arrive at a critical compressive stress. His deductions leave some uncertainty of magnitude of critical stress because of uncertainty of final shape of elliptic crack.

Primitive experiments on agar-agar, paraffin, and wax gave rough qualitative agreement with theory. Quoted estimates of radii of curvature (of the order of 10^{-8} cm) lead reviewer to believe that analysis of a continuum has outlived its usefulness in attempts at quantitative results. W. Kenneth Bodger, USA

3189. Ono, A., Supplementary note on the fracture of materials under thrust, *Memo. Fac. Engng. Kyushu Univ.* 12, 2, 217–221, Sept. 1950.

In this second note (see preceding review) numerous holes of small dimensions are supposed to exist in an infinite plate, being distributed more or less evenly over the plate and acting as the points of weakness due to the stress concentration.

From author's summary

3190. **Tungl, E., Contribution to the theory of the circular plate** (in German), *Federhofer-Girkmann-Festschrift*, Wien, Franz Deuticke, 387–396, 1950.

3191. **Mitrinovitch, D. S., Third method of integration of the Neményi-Truesdell equation** (in Serbian), *Bull. Soc. Math. Phys. Rep. Pop. Maced.* **2**, 1, 17–24, 1951.

Author continues his studies of the equation $F''/F + k(f''/f) = 0$, k being a constant, with the objective of finding explicitly a pair of functions f and F which satisfy it. When success is achieved, $r = f(z)$ may be interpreted as the meridian curve of an elastic shell of revolution, for which the Neményi stress functions, yielding a complete solution of the problem of extensional stress subject to unsymmetrical load and support, are $F(z)$ with $k = n^2 - 1$, n being an integer. The present method begins with an arbitrary functional relation $F = T(f)$ and from it constructs the solution

$$df \int \exp \int df\, fT''/fT' + kT = Ax + B$$

so that by means of two successive quadratures and one functional inversion, a meridian function f is obtained. In comparing this method with his two previous ones [AMR **4**, Rev. 1040; *Ann. Fac. Philos. Univ. Skopje, Sect. Sci. Nat.* **3**, no. 5, 1950; *J. Wash. Acad. Sci.* **41**, p. 129, 1951], author concludes that the first is the most complicated, while the second is the simplest; that all three may be generalized so as to apply to equations of much more general type; but that only the third, in more general form, can be applied to the reviewer's equation $F'''/F - (f'''/f'' + f'/f)F'/F + n^2 f''/f = 0$, which is the governing equation for the corresponding extensional displacements. [For the author's treatment of this latter equation, see Rev. 3187 in this issue.] The author has given elsewhere a more detailed treatment of his three methods in generalized form [*Ann. Fac. Philos. Univ. Skopje, Sect. Sci. Nat.* **3**, no. 6, 1950].

C. Truesdell, USA

3192. **Flügge, W., The relaxation method in statics of shells** (in German), *Federhofer-Girkman-Festschrift*, Wien, Franz Deuticke, pp. 17–35, 1950.

A short description of the general mathematical way to the solution of shell problems introduces the paper. The paraboloid of revolution serves as an example, for which the general solution is given. Southwell's relaxation method is applied to a similar shell with a cutout. The relaxation starts from values taken from the general solution. It proceeds through consecutive application to three grid systems, with gradually decreased mesh distances, using the values from the previous one as starting values. Accuracy of the final results is shown by a comparison to values obtained from a mathematical solution. Difficulties to overcome at the loci of singularity are pointed out.

There is no reference to the speed of convergence or the number of the relaxation steps involved. It will be very helpful to know how the accuracy of the starting values influences the amount of the computation work, especially in the case of wholly unconventional types of shells. D. Vasarhelyi, USA

3193. **Timo, D. P., Axial loading of a cylindrical container,** *Gen. Electr. Knolls Atom. Power Lab.*, Schenectady, Rep. KAPL 495, 50 pp., Mar. 1951.

Author presents curves which facilitate calculation of stress and deflection of cylindrical vessels with flat ends due to uniform normal loading applied to an end. Results are not directly applicable to hydrostatic loading, since cylinder wall is assumed unloaded. However, method of solution described and illustrated, using superposition and consistent deformations, is applicable to any symmetrical loading and to cases in which cylinder has an end flange. R. J. Roark, USA

3194. **Williams, S., Starkey, R. D., Leggett, D. M. A., et al., The use of rubber models in stress investigations,** *Aero. Res. Counc. Lond. Rep. Mem.* 2433, 22 pp., Aug. 1942, published 1951.

In part I the possibility of using rubber sheet subjected to large strains (of the order of 10 to 30%) for the purpose of stress investigations is examined, and reasons are given for expecting useful results from the application of the idea to aeronautical structural problems. In part II the method is used to explore the stresses around holes of various shapes, and variously reinforced, in flat sheets in tension. In part III the method is applied, first, to obtain the stresses around a semi-circular notch cut in the side of a sheet strip under tension, and, second, to obtain the stress distribution in a sheet strip lightened by a series of circular holes when the strip is subjected to shear forces.

From authors' summary

3195. **Zerna, W., Calculation of shells of arbitrary shape loaded at their boundaries** (in German), *Z. angew. Math. Mech.* **30**, 11/12, 370–374, Nov.-Dec. 1950.

Problem of thin elastic shells of arbitrary shape (loaded at the boundary) is solved by use of general coordinates and with notation of Ricci calculus. Mathematically, problem is expressed by a complex differential equation of the fourth order. The real part of the solution corresponds to normal displacement, the imaginary part to the stress function. By aid of these quantities, the other components of displacements, forces, and bending moments can be computed. Great value of paper lies in the possibility of solving problems of shells of arbitrary shapes; the theory hitherto presented usually deals with rotary shells only. In reviewer's opinion, it would be desirable to put all these rather "highly mathematical" formulas in a language more understandable to engineers. M. Hampl, Czechoslovakia

Buckling Problems

(See Revs. 3144, 3202)

Joints and Joining Methods

3196. **Stern, E. G., The nail—an indispensable fastener,** *Amer. Soc. mech. Engrs.* Paper no. 51-S-18 (mimeographed, 14 pp.), Apr. 1951.

3197. **Stern, E. G., Nails in end-grain lumber,** *Timber News* **58**, 2138, 490–492, Dec. 1950.

Comparative data are presented on the holding power of plain-shank and threaded-shank nails in end-grain vs. side-grain lumber.

From author's summary

3198. **Stern, E. G., Improved nails for building construction,** *Virginia Polyt. Inst. Engng. Exp. Stat. Bull.* no. 76, 23 pp., Sept. 1950.

Improvements in erection of structures can be attained by use of certain types of improved helically or annularly grooved nails for framing and for fastening of boarding, sheathing, siding, roofing, flooring, panelling, millwork, sheet-metal work, hinges, and fences. Field trials followed by small- and large-scale applications of the knowledge and experience gained have resulted in innumerable better built, more valuable structures during the past 15 years. The laboratory tests reported on in this bulletin not only confirm

this experience but also make it possible to present both engineering design data on improved nails and comparative data on structural improvements. From author's summary

3199. Egner, K., Load-carrying capacity and deformation of lumber joints assembled with large nails (in German), *Dtsch. Zimmermeister* **53,** 3, 1–9, Mar. 1951.

Forty structural joints, built with 2.2 or 2.8-in thick, green or air-seasoned German fir and assembled with 7.1 in. × 0.236 in. or 9.1 in. × 0.299 in., respectively, common wire nails in double shear, were tested immediately after nailing or after air-seasoning of the green-nailed members. The joints were stressed in tension parallel to grain of the three parallel members or in compression perpendicular to grain of the two parallel side members loaded by the perpendicular center member.

Since spacing from center to center of nails of 10 diam and end-spacing of 12 diam resulted in splitting, particularly of the air-dry lumber during assembly, the nails were also spaced 13 diam and end-spaced 15 diam. The tension and compression joints were loaded up to the design loads in steps of 4,400 and 2,200 lb, respectively, unloaded, repetitively loaded 12 times without interruption during loading, and finally loaded to the ultimate in steps given above. Observations were separately analyzed for fast- and slow-grown fir.

The test findings led to re-evaluation of the specified (1) nail spacing, (2) end spacing, and (3) offset of successive nails in a row.

E. George Stern, USA

3200. DeLollis, N. J., Rucker, N., and Wier, J. E., Comparative strengths of some adhesive-adherend systems, *Trans. Amer. Soc. mech. Engrs.* **73,** 2, 183–193, Feb. 1951.

Strength properties of various adhesive-adherend combinations are determined as one phase of an investigation of the nature of adhesion. The adhesives are polyvinyl acetate, cellulose nitrate, resorcinol resin, casein, gum arabic, natural rubber, and neoprene. The adherends are stainless steel, aluminum alloy, paper-phenolic laminate, glass, birchwood, and hard rubber. Properties studied are double-lap shear, tensile, long-time loading shear, and impact strengths. The tensile-adhesion and shear-strength values for a given adhesive-adherend combination do not differ greatly except for wood and paper-phenolic laminate, which are nonisotropic. The highest values (up to 3600 psi) are obtained with polyvinyl-acetate and cellulose-nitrate adhesives. The thermosetting resorcinol resin shows no appreciable flow in supporting a load of 680 psi for six months, whereas the thermoplastic polyvinyl acetate failed in 45 days under a load of 200 psi. The rubber-type adhesives, which are weak compared with the other adhesives in the static load tests, are definitely superior in the impact tests. Better correlation of shear strengths is observed with the moduli of elasticity than with the dielectric constants of the materials used in the various adhesive-adherend combinations.

From authors' summary

Structures

(See also Rev. 3397)

3201. Mudrak, W., The Cross method in rigid frame structures with non-straight rods (in German), *Federhofer-Girkmann-Festschrift,* Wien, Franz Deuticke, 255–274, 1950.

By "non-straight" rods, author means members curved or with corners between joints. Carryover and stiffness factors for such members are determined by elastic center method. Fixed-end moments are divided into symmetric and antisymmetric parts with Cross method applied to both. Sidesway effects are computed from the antisymmetric part and superimposed. Numerical examples of two- and three-story bents of two bays under unsymmetrical loading are presented.

Frank J. McCormick, USA

3202. Kirste, L., Buckling of frameworks normally to their plane (in German), *Öst. Ing.-Arch.* **4,** 2, 136–138, 1950.

Simple formulas for the lateral stiffnesses of joints of trusses are developed in terms of the dimensions of the members and the loads they carry. Lateral stiffnesses being known, limits to the stability in buckling normal to the plane of the truss are determined. L. E. Goodman, USA

3203. Efsen, A., Calculation of symmetric Vierendeel frames (in Spanish), *Cienc. y Tecn.* **114,** 575, 207–216, May, 1950.

The procedure is based on the method of primary moments described in the same publication [**112,** p. 323, 1949]. In this number, detailed calculations are shown for evaluating the stresses in the members of a symmetrical Vierendeel frame that is externally statically determinate but not symmetrically loaded. Formulas are given for the basic quadrilateral frame involved, and two examples are worked in detail. Conventional assumptions are made. Glenn Murphy, USA

3204. Symonds, P. S., A review of methods for the plastic analysis of rigid frames of ductile metal, *Grad. Div. appl. Math. Brown Univ.* A11-S6/86, 86 pp., May 1950.

This valuable and inclusive review of methods of plastic analysis of indeterminate, mild steel beams and rigid frames (limit design) gives a systematic account of extensive literature in this field, including author's original investigations. Plastic collapse loads under single type of loading are investigated by various methods: equilibrium conditions, inequality relations, least work principles. Method of estimating magnitude of deflections at imminent collapse is original and particularly valuable. Ultimate loads of structures subject to arbitrary and variable load patterns (shake-down) are investigated by systems of inequalities which are more general than previous treatments. A few numerical computations show shake-down loads to be not significantly lower than simple plastic collapse loads. If capable of generalization, this would be a practically important finding in view of the much greater complexity of elastic-plastic shake-down analysis as compared to determination of simple, plastic collapse loads. Though some of the proposed methods still seem too abstract for practical use, they represent a substantial step in the necessary generalization of plastic design methods. No account is given of any experimental research.

George Winter, USA

3205. Cervi, S., Cross method in most general form for plane structures (in Italian), *G. Gen. civ.* **88,** 10, 596–600, Oct. 1950.

The method of moment distribution is described for plane multiple frames. All the nodes are considered initially locked, the clamped-node reactions are computed and then, after unlocking one node, the residual reactions are distributed in the members having the common node considered. The nodes are unlocked, one after the other, and the distribution is repeated until the residuals are negligible.

In the plane of the frame, for each node, three degrees of freedom are considered: rotation, vertical displacement, horizontal displacement; and the unlocking occurs for each of these displacements. The unlocking of the only rotation, for instance, produces changes in the vertical and horizontal reactions, to be introduced among the residuals.

The method is clear in its concept. However, some doubt is legitimate about the rapidity of convergence of the procedure, which the author does not discuss. Carlo Riparbelli, USA

3206. **Grinter, L. E., Peller, C., and Butkus, J., Stress distribution in plastic range in a rigid frame,** *Weld. Res. Suppl.* **16,** 3, 125s–134s, Mar. 1951.

A welded structural frame under a few repeated loads carried beyond the elastic limit is studied. Although frame stress was relieved after welding, small residual stresses appear to have been present. A large number of Berry and SR-4 gages are used to observe elastic behavior and usual redistribution of stress after yield. Results check well with elastic theory, but insufficient data (plastic-hinge values, strain-hardening characteristics) are presented to assess quantitatively the plastic information.

Jacques Heyman, England

3207. **Roik, K.-H., On the calculation of continuous girders** (in German), *Bautechnik* (**Stahlbau**) **28** (20), 1, 10–13, Jan. 1951.

In the design of continuous beam and girder bridges some materials saving can be achieved by providing for predetermined support settlements. Paper shows how to calculate these settlements so as to obtain the economically most favorable bending-moment distribution. Principle is similar to that of prestressing. In three calculated examples, savings amount to 3–9% of total flange or chord material. George Winter, USA

3208. **Valentin, W., Diagrams. Influence lines and moments for continuous beams and frames [Diagramme. Einflusslinien und Momente für Durchlaufträger und Rahmen],** Wien, Springer-Verlag, 1950, 66 pp., 55 figs., 64 charts. $5.70.

The tables of special functions, influence coefficients, and influence lines in this book will greatly facilitate the analysis of continuous beams and of framed structures without sidesway. All data are presented for use by practicing engineers and every effort is made to prevent errors and to reduce the volume of computation required in the analysis of such structures.

Criteria for signs, and useful relations among external moments, moments at points of support, and internal moments at sections in the spans are developed in detail in the first 66 pages. Nothing more difficult than the slope-deflection relations is used in this development, but several coefficients are introduced to express relations between factors applicable to specific arrangements of beam, or beam and column elements. Once an engineer becomes familiar with these coefficients he will find that the 11 tables and 53 diagrams cover most practical framed structures under most practical distributions of load. The development of the coefficients is presented clearly and in detail. Limiting or approximate values are given where the use of such values will reduce the number of iterations required for an exact determination of the coefficients. The third significant figure may be estimated from the diagrams and the tables may be used with a minimum of interpolation. Joseph S. Newell, USA

3209. **Charlton, T. M., Some notes on the analysis of redundant systems by means of the conception of conservation of energy,** *J. Franklin Inst.* **250,** 6, 543–551, Dec. 1950.

Analysis of statically indeterminate structures depends upon equilibrium and geometrical compatibility. Equilibrium conditions are obtained from conservation of energy. Compatibility conditions are derived from conservation of complementary energy (area to the left of load-deflection curve). This leads to Engesser's principle that the partial derivative of complementary energy with respect to an internal force is zero. For linear elastic systems this is equivalent to Castigliano's principle of least work, inasmuch as complementary energy then equals strain energy. Self-straining is also considered and appendix treats direct application of conditions of equilibrium and compatibility to linear elastic frames. This approach apparently offers no practical advantage over relaxation methods. Its value lies in its direct development from fundamental energy relations. A reference to the concept of complementary energy not in bibliography is *Trans. Amer. Soc. civ. Engrs.* **107,** 765–803, 1942.

C. M. Tyler, Jr., USA

3210. **Meadows, R., Jr., Deflection tests of plastic models,** *Proc. Soc. exp. Stress Anal.* **8,** 2, 117–128, 1951.

Methods of testing plastic scale models of structural elements of gun turret and steam turbine casing are described in detail. Paper also describes control models of box-girder type used to correct for errors due to creep, temperature, and aging of cemented joints. Gordon P. Fisher, USA

3211. **Friedrich, E., Prestressed reinforced concrete beams in composite structures** (in German), *Federhofer-Girkmann-Festschrift,* Wien, Franz Deuticke, 161–180, 1950.

Composite structures find ever-increasing application in today's bridge building and superstructure work. The basic idea is: the concrete plate, being arranged above the steel girder, is to be connected with the latter in such a manner that a statically homogeneous system results. Author stresses various advantages connected with this building mode: (a) Both concrete and steel are used economically; (b) steel in considerable quantity is saved; (c) an over-all weight reduction of the structure results; (d) the steel girder serves as a basis for the concrete and the problems of erecting the structure are thus simplified; (e) careful calculations being assumed, overstresses can be avoided.

Author extends known calculations on composite structures to the case of prestressed steel girders. One main advantage of this latter type of supporting beams is a further saving in steel and further weight reduction of the structure.

Max A. Dengler, USA

3212. **Frazer, R. A., Aerodynamic oscillations of suspension bridges,** *Engineering* **171,** 4440, 270–271, Mar. 1951.

Failure of Chester bridge and Tacoma Narrows bridge in the U.S.A. is discussed briefly. Only bridges having solid sides and web depth of at least one fifth of bridge width are believed to vibrate vertically, referred to as "galloping." When a bridge is exposed to wind, deposition of oscillating ranges is expressed as V/nb, where V is wind speed, b is bridge width, and n a typical natural frequency. Lack of information on behavior of winds for suspension-bridge design is deplored by author.

Wind-tunnel analysis for Severn Bridge model is described and possible modes of design suggested. These experiments are conducted by two methods. Simpler but less accurate one is to use rigid sectional model representing only sample length of prototype. Model is mounted on springs in wind tunnel with span horizontal and deck at various angles of incidence and zero yaw, and wind-speed ranges over which sustained pitching oscillations or vertical translational oscillations occur are observed. These motions are two-dimensional equivalents of twisting and bending oscillations in prototype. Second and more elaborate method is to test a full model bridge with dimensions, masses, and stiffness scaled so as to represent full bridge. Originally chosen as 1:100, the linear scale of Severn Bridge model is further modified to 1:32 to allow reproduction of finer structural details. No specific mention is made of the theoretical and experimental work of American investigators like Steinman, Bleich, Farquharson, and others, as outlined by Ghaswala [*Civ. Engng. Lond.* **45,** 531,

532, 533; 586–589, 646–649, 725–727; Sept., Oct., Nov. 1950] as these contributions cover most of the work so far described.
S. K. Ghaswala, India

3213. Dörr, J., Remarks on the elasticity theory for a parallelogram-shaped plate, bordered by rigid pin-jointed rods (in German), *Öst. Ing.-Arch.* **5**, 1, 34–36, Feb. 1951.

3214. Kuhelj, A., On the determination of internal forces in two-spar wings (in Slovenian), *Tehn. vis. Šola, Ljubljana, Acta tecn.* **1**, 12 pp., Aug. 1950.

Purpose of paper is to determine in an as direct a way as possible the internal forces in the members of a two-spar wing with a torsion-resisting skin under the influence of the normal component of external loads. Roxbee Cox, Hanson, and Sandford have shown that the elastic center exists for a very general type of wings, but, generally, its position depends not only on its structural characteristics but also on the spanwise distribution of external loads. To avoid some of the calculations involved when decomposing the influence of loads into the bending action and torsion it is proposed, first, to calculate the bending moment M_ξ of external forces and the moment M_η about the axis of the front spar, and then to determine the resultant bending moment M_2 in the rear spar directly, which is caused by the direct bending of the wing and by the differential bending in torsion. The differential equation for M_2 is given and the discussion of its solution is followed by an example, in which a wing of constant stiffness along the span is dealt with in some detail.
From author's summary

3215. Hall, A. H., Report on observations of the behaviour of a family of plastic wing models under dead weight and aerodynamic loads, *Nat. Res. Counc. Canad. mech. Engng. Rep.* MM-222, 10 pp., May 1950.

Plastics, with their low stiffness characteristics, were selected since it was expected that complete torsion cells representative of actual wings could be used and measurable deformations observed at relatively low wind-tunnel speeds. Cellulose acetate showed reasonable linearity up to about 500 psi in tension and 1000 psi in shear, under normal conditions of temperature and humidity.

The general conclusions are generally negative due to unforeseen difficulties resulting from wind-tunnel turbulence, excessive movement of the shear center, and change in stiffness under shear load. However, the report discusses data, procedures, and conclusions regarding suitability of cellulose acetate for models, structural behavior of models, and effect of wing taper on wing-torsional divergence. Frederick K. Teichmann, USA

3216. Walter, M. A., Structural load measurements on complex aircraft components using strain-gage summation circuits, *J. aero. Sci.* **18**, 2, 101–106, Feb. 1951.

Paper presents a method for measuring incremental structural loads on complex aircraft surfaces without previous knowledge of load distribution. Method makes use of electric strain gages and a suitable electric circuit with a single-channel output to a recording system. Static test calibrations indicate a maximum error of 3.7%. Method is particularly useful in measuring net loads in flight under dynamic conditions. Ai-ting Yu, USA

3217. Waagepetersen, A., On the design of wooden roof bents (in Danish), *Bygnstat. Medd.* **19**, 3, 93–106, 1948.

Paper gives formulas for the support reactions and joint moments of simple wooden roof bents. The bent treated consists, generally, of two rafter beams, supported at the outer ends by two columns with knee braces, and connected near the top by a horizontal brace. Also, various special forms of the above are discussed briefly. The loads considered are symmetric, dead load, directly and indirectly acting, wind load on one side, and snow load on one side. Joints at the supports are considered as hinges, and the bent is treated as a statically indeterminate structure with one redundant member. Tage A. Mortensen, USA

3218. Bächtold, J., Crack-proofness of reinforced concrete, a requirement of underground and water works (in German), *Schweiz. Bauztg.* **68**, 31, 415–417, Aug. 1950.

3219. Johnson, A., Concrete beams with compression reinforcement (in Swedish), *Inst. Byggnadsst. Medd.* no. 4, 15 pp., 1950.

First part of paper deals with various methods used in design of concrete beams provided with compression reinforcement. A description is given of the method stipulated in the Swedish standard specifications, the method given in the regulations of the American Concrete Institute, and the method of limit design. Author also advances a modified method of design which may conveniently be used in those cases where the classical method or a similar method is prescribed for the design of the cross sections provided with simple reinforcement. In the case of transition from simply reinforced cross sections to those provided with double reinforcement, the method of design suggested in this paper results in equivalent structures. The method devised by author is based on the principle of addition, and may be regarded as a modified method of limit design. The allowable moment constitutes the sum of the allowable moment computed in accordance with the specifications or regulations for a simply reinforced cross section having a ratio of reinforcement and the allowable moment due to the compression reinforcement and the corresponding amount of tension reinforcement.

In the second part, an account is given of a series of tests made on concrete beams with compression reinforcement. The maximum ratio of reinforcement used in the tests was 2.5%. Agreement between values of the ultimate moments observed in the tests and calculated by means of the limit design method, was good. Magnitude of the ultimate loads was found to be independent of whether beams were reinforced with stirrups or not. Buckling of compression reinforcement took place in both cases after ultimate load had been reached and had slightly decreased. But after buckling of compression reinforcement, load-bearing capacity of the beams without stirrups decreased more rapidly than that of the beams provided with stirrups. Consequently, total carrying capacity of the beams is smaller in the absence of stirrups, and this can be of importance in those structures which are liable to be submitted to dynamic forces.
From author's summary

3220. Williams, D., and Hopkins, H. G., Rib loads at changes of section in a torsion box, *Aero. Res. Counc. Lond. Rep. Mem.* 2503, 8 pp., June 1945, published 1951.

When the width of a torsion box is suddenly increased from one cell to two cells, the consequent redistribution of torque cannot be effected entirely by a boundary rib which is of finite stiffness. Increments of the applied torque T_0 are carried into the added cell by the successive ribs. Denoting the portion of T_0 carried into the rear cell by the i-th rib as $r_i T_0$, the strain energy of the system is expressed by author as a quadratic in the r's. By the principle of least work, this is minimized with respect to each r to obtain a system of linear equations in the r's. Manipulation of these leads to a neat difference equation, the roots of which give a

general solution for r_n which is particularized by substitution into a pair of the linear equations. A simple numerical example is given. In an appendix by H. G. Hopkins, the method is extended to case of unequal rib stiffnesses. In practice, reviewer believes, only a small number of ribs may be assumed to cooperate in the redistribution. The energy formulation, which would be used in any event, thus leads to a small number of linear equations in the r's which may be solved directly.

Author does not state that a similar problem arises at any rib where a large increment of external torque is applied, frequently as a concentrated load not acting through the elastic axis. Also not mentioned is the contribution of the spars to the torsional resistance by virtue of warping stresses in the longerons.

John E. Goldberg, USA

3221. **Banerjee, S. P., Design of a self-supporting chimney foundation,** *Civ. Engng. Lond.* **45,** 534, 790–792, Dec. 1950.

Proposed method of design refers to anchor-bolted connection to concrete slab of free-standing stack. Author presents a direct design involving an equivalent steel strip in place of anchor bolts in tension as an alternative to usual trial-and-error method based on repeated trial assumptions for neutral axis location. Modification of basic procedure by variation of design-stress ratio or modular ratio in order to achieve general economy in design is discussed. With general equation in hand, arithmetical computation is considerably reduced over that required for trial-and-error procedure. Gordon P. Fisher, USA

3222. **Heldenfels, R. R., A numerical method for the stress analysis of stiffened shell structures under nonuniform temperature distributions,** *Nat. adv. Comm. Aero. tech. Note* 2241, 45 pp., Nov. 1950.

A numerical method, employing matrix iteration, is applied to determine the effects of nonuniform temperature distributions, such as those produced by aerodynamic heating, on an idealized structure consisting of a rectangular panel bounded on two parallel sides by extensionally flexible stringers and on the other two sides by rigid bulkheads. The numerical method is discussed as to validity of basic assumptions, and idealization of an actual structure. Conclusions drawn are that the method provides a means for determining accurately all types of secondary stresses in complicated structures that cannot be satisfactorily analyzed by simplified methods; it is sufficiently flexible to cope with a wide variety of problems; and it involves only simple arithmetic easily handled by automatic computing machinery.

Frederick K. Teichmann, USA

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 3181, 3204, 3249, 3254, 3266, 3267, 3426)

3223. **Gubkin, S. I., Diagrams of schemes of mechanical states** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk*, no. 8, 1165–1182, Aug. 1950.

Paper deals with states of plastically deformed bodies. If volume constancy is assumed, every mechanical state is determined by the "relative minimum strain" $\delta = \epsilon_1/|\epsilon_3|$ and by the "relative average stress of first kind" $\alpha_1 = p/S_i$, or the "relative average stress of second kind" $\alpha_2 = p/|S_3|$. ϵ_1 and ϵ_3 are minimum and maximum principal strain, respectively, according to their absolute value; $3p$ is the sum of principal stresses $|S_1| < |S_2| < |S_3|$ and $2S_i^2 = (S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2$. Therefore, every point of a δ, α_1 diagram or a δ, α_2 diagram represents a defined mechanical state. Both diagrams are divided into several fields in which ductile and brittle materials differ in their behavior. With these diagrams on hand, materials and technical shaping processes (rolling, forging, drawing, etc.) are classified. In the plastic deformation of polycrystalline metals, author distinguishes a mechanism with diffusion and one without diffusion. The former includes the amorphous mechanism, proceeding near the crystal boundaries, and the slip process within the crystals. Example for mechanism without diffusion is twinning process.

H. Mussman, Germany

3224. **Hill, R., Lee, E. H., and Tupper, S. J., A method of numerical analysis of plastic flow in plane strain and its application to the compression of a ductile material between rough plates,** *J. appl. Mech.* **18,** 1, 46–52, Mar. 1951.

A brief outline is given of the equations of plastic flow appropriate to problems in which the plastic strains are large enough to justify neglect of the elastic strains. The material is assumed to have a well-defined yield point and to show no work-hardening. These results are applied to the subject problem and a numerical solution is obtained by replacing the differential equations by corresponding finite difference equations. Boundaries of the plastic regions are determined for one value of the block length/height ratio and the slip-line and velocity fields are plotted. An analytical method of solution is given but the complication of the integrals involved renders its general use impossible. It offers a partial check on some of the numerical results obtained. Methods used by previous writers are criticized and it is shown that, for a complete solution of a problem of this type, consideration of the velocity field is essential. This has been overlooked by some previous writers. An analogy in plasticity theory of Saint-Venant's principle in elasticity is mentioned.

The substance of this paper has been incorporated, with the consideration of a number of other allied problems, in the book, "The mathematical theory of plasticity" by R. Hill [AMR 4, Rev. 2471]. W. M. Shepherd, England

3225. **Inouye, K., A modern theory on the structure and caking properties of coal from the rheological viewpoint,** *J. Colloid Sci.* **6,** 2, 190–210, Apr. 1951.

To determine why caking coals fuse and swell at high temperature, measurements were made of Young's modulus E at room temperature of a large number of coals. Method was to determine resonance frequency of bar specimen in flexural vibrations. E varies with moisture content, volatile matter, ash, and bitumen. Observed relationships vary with age and type of coal. Empirical dependence of vo ume of ash φ is $E = E_0(1 + K\varphi)$, suggesting effect of fillers on modulus of rubber. Conclusions: Caking requires small E_0 and large K. K is interpreted as degree of solvation of organic molecules with "filler" (ash) particles suspended in matrix of modulus E_0. Physical significance is that, for caking, intermolecular forces of coal molecules should be weak and molecules should be strongly solvated around ash particles. Reviewer notes bad scattering of data underlying some of reported relationships. Author's argument makes implicit assumption that E_0 at room temperature predicts softening point of matrix. Melvin Mooney, USA

3226. **Lindquist, C. G., and Sierichs, W. C., The measurement of the flow properties of a pseudoplastic with a concentric cylinder viscometer,** *J. Colloid Sci.* **6,** 1, 33–41, Feb. 1951.

The rate of shear across the gap of a viscometer is not constant, hence it measures the absolute viscosity of a Newtonian fluid only. For use with a pseudoplastic system, a MacMichael viscometer having four inner cylinders was employed and the apparent viscosity determined for four clearances ranging from 0.41 to 0.12 cm. By testing with either the inner or outer

cylinder fixed, the apparent viscosity was measured for eight shear rates and the true viscosity at the mean shear rate determined by extrapolation to zero clearance.

Retesting the set for a number of different rates of shear enabled the complete shear-stress/shear-rate curve for a given material to be plotted over a range of stress. The accuracy obtainable from a single pair of cylinders can also be determined from the above data. W. Lethersich, England

3227. Singleterry, C. R., and Stone, E. E., Rheological properties of a lubricating grease, *J. Colloid Sci.* **6,** 2, 171–189, Apr. 1951.

Results described here show that when the phenomena of flow in a capillary are separated from accompanying effects such as piston drag, entrance losses, and temperature rise during flow, a shear-stable grease of the 1468 type behaves substantially as a Bingham plastic whose flow can be specified in terms of yield value and mobility. The yield value so obtained is in reasonable agreement with that measured directly. The reciprocal of the mobility, which can be identified with the limiting apparent viscosity approached at high rates of flow, is from two to five times the viscosity of the diester fluid present in the grease. These magnitudes are reasonable in the light of the volume and particle shape of the suspended soap phase.

A graphic method has been developed for the analysis of flow data for Bingham plastics in terms of the Buckingham equation for plastic flow in tubes of circular cross section. This treatment permits direct computation of both the yield value and the mobility of such a plastic from data for flow under two suitable pressures without resort to the trial-and-error operations previously employed for this purpose. From authors' summary

3228. Scheele, W., and Timm, T., On the application of the Waele-Ostwald interpolation formula in rheology (in German), *Koll. Z.* **121,** 3, 140–143, Mar. 1951.

Formula $v = Kp^n$, where v and p are observed kinematical and dynamical macro-quantities, was applied to measurements with Hoeppler consistometer on large-number polymers, bitumens, tars. For each system, n plotted against log K gives a straight line, straight lines for different systems being parallel. This seems to point to intrinsic property of non-Newtonian flow.

M. Reiner, Israel

3229. Müller, F. H., Elastic dispersion and kinetic equation of state (in German), *Kolloid Z.* **120,** 1–3, 119–133, Jan. 1951.

Review article. Viscoelastic and plastic-elastic properties of high polymer materials. Phenomenological theories.

Melvin Mooney, USA

3230. Mardles, E. W. J., The rheology of lubricant films, *Brit. J. appl. Phys. Suppl.* **1,** 7–12, Jan. 1951.

Author measures the rate of radial spread of a pool of liquid over polished horizontal surfaces and recognizes that the surface tension is the main controlling force of this physical occurrence and that its rate varies with the material of the surface and the liquid.

Author then studies the rate of radial spread of a pool of liquid between horizontal optical flats approaching or receding in a normal direction. He observes that it differs from the rate calculated according to the hydrodynamic theory. He also finds a dependence on the material of the flats and the liquid. That is no surprise, because the hydrodynamic theory does not account for surface adhesion forces. Moreover, several liquids have a considerable rigidity which influences the flow.

Further, author finds that if a flat slider is allowed to sink into a pool of liquid, the tangential force required to start the motion increases as time elapses, because the film thickness decreases and the area of the attack of tangential stresses increases. For the same reason, the ease of sliding increases if, with change of the material, the rate of radial flow has decreased. However, it appears that in the case of low pressures the coefficient of friction has disproportionately high values. Ulrich Rost, Germany

3231. Mii, H., Plastic deformation of light-metal bars strained with combined tension and torsion, *J. Jap. Soc. appl. Mech.* **3,** 20, 196–198, 204, 1950.

Method for calculating stress distribution in circular bar in plastic range with work-hardening under combined axial and torsional loads is based on plastic deformation theory, with axial and torsional loads applied simultaneously and proportionally. Deformation of the material in strain-hardening range is assumed to follow the "maximum shear stress theory," with the ratios of principal shearing strains equal to the corresponding ratios of principal shearing stresses. The radial and circumferential stresses are taken to be zero, and, assuming the elastic components of strain to be negligible as compared to the plastic, the condition of incompressibility is used. An illustrative example is given with different ratios of axial to torsional loads.

T. H. Lin, USA

3232. Aronofsky, J., Evaluation of stress distribution in the symmetrical neck of flat tensile bars, *J. appl. Mech.* **18,** 1, 75–84, Mar. 1951.

Author shows that the stress distribution at fracture for round and flat tensile bars can be determined approximately from the theory of plastic state by means of some simplifying suppositions. In this method the strain-hardening function of the material and some additional measurements of strain are necessary. With regard to the fracture load, author believes his calculations agree well with measurements. H. Neuber, Germany

3233. Kammerer, A., Internal friction of solids and viscosity (in French), *C. R. Acad. Sci. Paris* **231,** 23, 1285–1286, Dec. 1950.

Damping of solid materials increases with temperature. It would therefore seem that this effect cannot be considered as a viscosity since viscosity decreases with increasing temperature. This contradiction is only apparent and can be explained by a decrease in elastic modulus larger than a decrease in viscosity.

From author's summary by A. Yorgiadis, USA

3234. Ter Haar, D., A phenomenological theory of viscoelastic behaviour. III, *Physica* **16,** 11–12, 839–850, Dec. 1950.

[See AMR **4,** Rev. 2036.] Paper refers to steady-state behavior of viscoelastic solids under sinusoidally varying stress or strain. The expressions for complex elastic modulus and coefficient of viscosity are given in terms of the relaxation-frequency spectrum. Several approximation methods are given and discussed critically for deriving this spectrum from experimental modulus and viscosity data. Finally, methods are discussed which permit determination of the complex modulus from the amplitude and phase characteristics obtained with standing and with traveling waves.

B. Gross, Brazil

3235. Shevchenko, K. N., Elasto-plastic problem for a heavy half-space with a vertical cylindrical opening (in Russian), *Prikl. Mat. Mekh.* **14,** 6, 587–592, Nov.-Dec. 1950.

In cylindrical coordinates (r, ϕ, z), with z down, material occupies region $r > a, z > 0$. It is incompressible, obeys deformation law of plasticity, has sharp yield point followed by hardening

along linear stress-strain curve, and is subject to no applied forces except its own weight. Besides simplifications resulting from axial symmetry, author assumes $\tau_{rz} = 0$; then from stress-strain relations, $\gamma_{rz} = 0$. He obtains, in closed parametric form, expressions for ϵ_r, ϵ_ϕ, and ϵ_z and for position of elastic-plastic boundary. His solution satisfies the equilibrium equations and one compatibility condition, that involving ϵ_r and ϵ_ϕ. No proof is given that it satisfies the compatibility condition imposed on ϵ_ϕ and ϵ_z by setting $\gamma_{rz} = 0$. In fact, for values of z where author finds that a plastic zone exists, his solution in the elastic zone can easily be shown to violate this condition. Reviewer concludes that $\tau_{rz} \neq 0$ and that author has not solved the stated problem.

William Fuller Brown, Jr., USA

3236. Seitz, F., The generation of vacancies by dislocations, *Phys. Rev.* **79,** 6, 1002–1003, Sept. 15, 1950.

Several processes, such as darkening of alkali halides by x- and cathode-rays, increase of ionic conductivity during plastic deformation, and motion of matter during diffusion (Kirkendall effect), require generation of vacancies with a density of 10^{18} — 10^{22} per cc in small volumes of about mosaic dimensions. Such densities cannot be explained by assuming freezing-in on cooling from melting point only. Author discusses the following possibility. Crystal may contain a small planar disk of interstitial atoms of about five lattice parameters in linear dimensions. This forms a small dislocation ring which can grow by taking atoms from the neighboring completed plans, thereby forming vacancies. If one such disk is contained more or less in each plane in the considered volume, an almost unlimited number of vacancies may be generated. Isolated disks are improbable in crystals with predominant effects of vacancies, as they are annihilated by the latter. The activation energy should be of the same order as that required to form a surface vacancy. During plastic deformation a moving dislocation acts as an equivalent of a large number of interstitial disks, as each segment of edge type may produce vacancies.

Also by screw dislocations vacancies may be formed. An initial small interstitial disk grows between the spirals of the dislocation, thus forming a spiral plane, the edge of which lies on a double cone with common base, whose apexes point in opposite directions and whose axis is parallel to the dislocation axis. This edge forms the line of a new dislocation, called spiral prismatic dislocation. The initial interstitial disk may be replaced by an edge dislocation with proper orientation.

Albert Kochendörfer, Germany

3237. Seitz, F., Spiral prismatic dislocations and the origin of slip bands, *Phys. Rev.* **79,** 6, 1003–1004, Sept. 15, 1950.

Spiral prismatic dislocations, closely related to those described in the paper reviewed above, may be formed in such a way that vacancies condensate along a screw dislocation, beginning with a short length of the dislocation and continuing in the planes normal to the axis of the dislocation. In a metal such as copper, about 10^{12} "precipitations" of this form per cc should be generated, each of them containing of the order of 10^7 vacancies. By slowly cooling from melting point, the energetically most stable form with one revolution of the spiral may be formed, but at short time cooling the spiral may have a number of revolutions. With the above value of the density of vacancies, an approximate calculation gives the following numerical results: Difference from 180° of the opening angle of the dislocation cone $\sim 2°$; radius of the base of the cone $\sim 10^3a$ (a atomic distance); lateral distance of two successive revolutions normal to the axis $\sim 10^3a$ at one, and $\sim 10^2a$ at 8 revolutions; energy per precipitated vacancy $\sim 5.10^{-3}$ev or equivalent ~ 100 cal/mole. These results show that these dislocations can contribute essentially to the mosaic structure. They give angles of rotation of about $^1/_2°$ between neighbored blocks and explain the relative stability of this structure on annealing. Furthermore, these dislocations may explain the regularity of slip bands since those parts of the spirals which are tangent to a given slip plane satisfy, in an almost ideal manner, the conditions of multiplication according to Frank and Read. As the thermal agitation will favor this process, the formation of slip bands should be temperature dependent. Multiplication, however, is not necessary if there are as many as 10^{12} dislocation rings per cc.

Albert Kochendörfer, Germany

Failure, Mechanics of Solid State

(See also Revs. 3188, 3189, 3232)

3238. Walczak, J., Modern measure for the fatigue of materials (in Polish), *Arch. Mech. stos.* **3,** 1, 5–26, Mar. 1951.

Main subject of paper is the comparison of the recently proposed theory of fatigue by Roš and Eichinger with the theory of Huber, which was proposed in 1904 and which author considers to be the only correct one. He stresses in particular that the similarities between the Roš-Eichinger criteria and those of Huber are purely formal and have no physical picture in common. The new theory is considered merely as an attempt to revive the old Mohr theory, which the author believes to be completely erroneous.

Roman Smoluchowski, USA

Design Factors, Meaning of Material Tests

3239. Pugsley, A. G., Concepts of safety in structural engineering, *J. Instn. civ. Engrs.* no. 5, 5–31, Mar. 1951.

A most interesting and worth-while historical review of the concept of safety in engineering, with particular emphasis on the new lines of thought in recent years in connection with the airplane. The engineering tradition in this respect has developed by a process "rather like that which has provided the common law; and it is a process the fruits of which can be seen in the different customs of different branches of structural engineering." Author has rendered a great service in calling attention to the fact that conventions of safety represent codification of experience. It can never fully safeguard against unknown modes of failure. Milestones of progress are usually associated with the emergence of new phenomena, such as brittle fracture of welded ships and flutter phenomena in airplanes and suspension bridges, and so on. Paper concerns itself almost wholly with the structural field. Similar examples may be found in abundance in the machinery field.

C. Richard Soderberg, USA

Material Test Techniques

(See also Revs. 3248, 3249, 3251, 3262)

3240. Steward, S. P., Measurement of tensile strength of suture materials, *J. sci. Instrum.* **28,** 4, 114–115, Apr. 1951.

A machine designed to measure breaking load and extensibility of surgical catgut is described. A horizontal track, carrying a weighted trolley, is allowed to tilt under the force of gravity. The rate of tilting is controlled by a piston provided with a leak moving in a cylinder of oil. Material to be tested is attached to a fixed point and to one end of the trolley. As the track tilts, a drum driven by a friction drive rotates and, on paper covering its surface, a writing point records the extension of the material and the load at which it breaks.

From author's summary

3241. Smith, F. C., Howard, D. M., Smith, I., and Harwell, R., Fatigue testing machine for applying a sequence of loads of two amplitudes, *Nat. adv. Comm. Aero. tech. Note* 2327, 31 pp., Mar. 1951.

This report describes the construction, operation, and calibration of two nominally identical fatigue-testing machines built at the National Bureau of Standards. These machines provide a means of applying to a specimen a sequence of two sinusoidally varying axial loads of different amplitudes with the mean load remaining constant, each load being applied for a predetermined number of cycles. It is possible to continuously measure the loads once established to an accuracy of ±3%.

A few preliminary tests made with these machines on a sheet material indicated that the loads once set remained constant to within ±1% for the necessary number of loading cycles.

From authors' summary

3242. Jellinghaus, W., New instruments for nondestructive testing on magnetic basis (in German), *Arch. Eisenhüttenw.* **22,** 3/4, 111–115, Mar.-Apr. 1951.

Author reviews new instruments developed during the last years by F. Förster and Reutlingen (Ferrotest instrument, crack detector, crack screening instrument, and sorting instrument). Ferrotest instrument works with alternating current (50 cps) using the induction method and measuring the difference between sample and a standard. Sensibility is heightened by choosing a different range of phase angles in the voltage time curve respective to the nature of faults. The other instruments work with field measuring probes [physical principles reviewed by Wurm, M., *Z. angew. Phys.* **2,** 210–219, 1950]. Crack detection consists of measuring, by a pair of probes, the gradient of field strength at the surface of the magnetized sample; for sorting of materials the pole strength is measured by one probe only. By the use of probes an increased sensibility and more convenient handling have been obtained. Author notes that hopeful aspects for the problems of nondestructive testing are seriously reduced by the need for considerable principal investigations on the relations between indication and real dimensions of faults, before applying the new instruments in engineering practice. Reviewer agrees to this statement and adds that a more detailed theory by Förster himself would be of great importance. Herman Möller, Germany

3243. Krainer, H., Nondestructive material testing of materials in Austria (in German), *Metall* **5,** 1/2, 18–20, Jan. 1951.

3244. Förster, F., New methods in nondestructive material testing and their principles (in German), *Metall* **5,** 1/2, 20–21, Jan. 1951.

3245. Loewen, E. G., Marshall, E. R., and Shaw, M. C., Electric strain gage tool dynamometers, *Proc. Soc. exp. Stress Anal.* **8,** 2, 1–16, 1951.

Designs and methods for building dynamometers are presented which use wire strain gages for measuring rapidly varying forces or torque in planes, drills, grinders, and lathes. Also, suitable commercial instruments for indicating or recording data are reviewed.

C. R. Freberg, USA

3246. Pugh, E. M., von Heine-Geldern, R., Foner, S., and Mutschler, E. C., Kerr cell photography of high speed phenomena, *J. appl. Phys.* **22,** 4, 487–493, Apr. 1951.

Visible light photographs have been obtained of metal jets squirted from the lined conical cavities of high explosive charges. Since these jets travel through air at nearly meteoric velocities (7 to 12 × 10^5 cm/sec), their front ends are heated to incandescense and vaporized. The remainder of the jet is relatively nonluminous and is photographed by synchronizing a Kerr cell shutter (exposure time < 1μ sec) and an exploding wire light source (peak intensity 4 × 10^6 candle power) with the phenomenon. Schlieren-type photography cannot be used because of the luminosity accompanying the phenomenon. Detail is obtained in the photographs by using a large lens with a 7-in. focal length. To maintain the effective aperture at *f*/4 requires a large Kerr cell which in turn requires a 25,000 volt pulse for its operation.

The technique is used in studying the action of the jets on steel, water, glass, and Plexiglas. It is also used in studying the propagation of shock waves in solids and liquids when these phenomena are due to the action of metal jets or to more direct action of explosives. From authors' summary

Mechanical Properties of Specific Materials

(See also Revs. 3110, 3115, 3200, 3225, 3229, 3263)

3247. Tottle, C. R., A note on the measurement of stress relief, *Metallurgia, Manchr.* **43,** 257, 148–150, Mar. 1951.

A creep-testing machine has been adapted for measuring stress relief during a heat-treatment cycle, enabling stress, extension, and temperature to be plotted against time on the same graph. Correction for thermal expansion is made by a precalibration under a small load of 0.05 tons, and adjustment of the straining gear during the actual experiment according to this calibration. A high-duty gray cast iron, an ordinary gray cast iron, a cast steel of 0.25% carbon, and a 66/34 cast brass were used to illustrate the principle. Curves obtained were all similar, the rate of deformation being the chief variable. Stress relief occurs rapidly as temperature rises and is well advanced when the maximum is reached. Little advantage appeared to be gained by continuation of heat treatment after the maximum temperature was achieved throughout the assembly. From author's summary

3248. Kinsey, H. V., An evaluation of the effective gage-length equivalent of the fillet and shoulder of the gage length portion of a tension test bar under creep and stress-rupture conditions, *Amer. Soc. Test. Mat. Bull.* no. 171, 60–62, Jan. 1951.

Author considers the errors introduced into creep measurements when extensometer is attached to over-all test specimen (gage length, fillets, shoulder). He finds that errors are larger than ±1% unless gage length is at least 8 in. His calculations are based on: Inconel X at 1500 F, alloy S-816 at 1350 F and 1500 F, alloy 73 J at 1500 F. Aris Phillips, USA

3249. Neurath, P. W., and Koehler, J. S., Creep of lead at various temperatures, *Nat. adv. Comm. Aero. tech. Note* 2322, 32 pp., Mar. 1951.

A creep apparatus was constructed, capable of measuring the stress-strain-time relation in the strain range 10^{-4} to 10^{-2} in./in. (smallest readings are about 2 × 10^{-6} in./in.) and at temperatures down to that of liquid nitrogen. Before completion of this apparatus, data at room temperature were obtained with a preliminary model.

Single crystals of lead were grown, some for the preliminary tests and some of a special shape for the final apparatus, and these were oriented by x-ray analyses. In addition, some copper and two zinc crystals were grown and tested.

Results indicate: (1) A very slight change, if any, of the yield point of lead crystals occurs between −190 and 30 C. (The yield point has been taken as that given by the resolved shear stress necessary to produce a strain of 10^{-3} in./in. within a few hundred

minutes.) (2) A radical change of the shape of the stress-strain-time curves occurs with decrease in temperature. (3) The stress-strain time curves for copper at room temperature are similar in shape to those for lead at −190 C, yet they cannot be made to coincide with the lead curves by changing the temperature at which the experiment is performed. The copper crystals will presumably always be several times as strong, even compared with lead crystals at very low temperatures. (4) Some work-hardening of lead takes place at room temperature and is only partially removed by annealing at room temperature even for periods of several weeks. (5) Working of the crystal influences creep rates more easily and more permanently than it does the yield point. (6) Zinc is appreciably weaker than lead at room temperature. The effect of orientation is noticeable, and the calculation of resolved shear stress brings the yield-point values into fair agreement. From authors' summary

3250. **Head, A. K., Statistical properties of fatigue data on 24S-T aluminum alloy,** *Amer. Soc. Test. Mat. Bull.* no. 169, 51–53 Oct. 1950.

Results of rotating cantilever fatigue tests of 185 specimens of 24S-T aluminum alloy with seven different surface finishes were used to test four hypotheses on the constancy of scatter at different applied stresses. These hypotheses are: Scatter in values of log N at any particular stress is the same at all stresses for each surface finish. Scatter in values of applied stress at any particular life N is the same at all N for each surface finish. Scatter in a direction normal to the S-log N curve is the same at all points on the curve for each surface finish. Scatter in values of applied stress at any particular life N is the same fraction of the applied stress at all N for each surface finish. It is shown that none of the four hypotheses given above adequately fits the data. The distribution of values of log N is shown to be approximately normal. From author's summary

3251. **Anonymous, Fatigue tests of beams in flexure,** *Weld. Res. Suppl.* **16, 3,** 105s–115s, Mar. 1951.

These tests were conducted at the University of Illinois and are reported more fully in *Engng. Exp. Sta. Bulls.* **377** and **382.** Twenty-seven types of structural beams were subjected to unidirectional bending stress cycles, 150 times per minute. Empirical equations were used to convert the data to fatigue strengths at 100,000 and 2,000,000 cycles.

Results show that any plain-rolled steel beam without attachments or flange holes has greater fatigue strength than any cover-plated beam or built-up beam of the same section modulus. This is due to the severe stress raisers at regions of welds or rivets. For a life of 2,000,000 cycles, the plain beam had a fatigue strength of 31,200 psi; beams with full-length welded cover plates from 16,500 psi to 22,800 psi; beams with partial-length welded cover plates from 8,200 psi to 14,200 psi; and beams with riveted cover plates from 12,400 psi to 18,000 psi. Continuous fillet welds afforded the best means of attaching cover plates to beams, followed by rivets and intermittent welds in that order.

Alexander Yorgiadis, USA

3252. **Fukui, S., and Sato, S., On the fatigue of work-hardened steel** (in Japanese), *Rep. Inst. Sci. Technol. Tokyo* **4,** 7–8, 210–215, July-Aug. 1950.

In a previous work, Haigh-type tensile and compressive fatigue limits were studied on specimens of ordinary constructional steel after being plastically deformed by statical tensile or compressive stresses. In this paper, Ono-type rotational bending fatigue limits are studied in the same way. Arranging the experimental results by the absolute values of natural strain corresponding to the preworking stresses, fatigue limits change similarly both for tension and compression. Comparing with the annealed states, the fatigue limits decrease by about 4% for strain smaller than about 3%, and then the limits raise to about 15% for the larger strain. This tendency seems to be similar to that of yielding point for bending. The changing rates of rotational bending fatigue limits are similar to those for the tension compression fatigue. From authors' summary

3253. **Glantz, O. J., and Halsted, L. E., Mechanically determining the time of set of Portland cement by means of the spissograph,** *Amer. Soc. Test. Mat. Bull.* no. 170, 79–81, Dec. 1950.

In an effort to relieve an operator of the responsibility of intermittently checking time of set on cement samples, an automatic machine has been devised. Test results shown include both the conventional hand method vs. the mechanical method, both on neat cement and mortar. Conclusion is that it is possible to do a satisfactory job of determining mechanically the time of set, particularly on mortar samples. From authors' summary

3254. **Blair, G. W. S., and Baron, M., The hardness and strain-hardening of plasticine,** *Brit. J. appl. Phys.* **2,** 3, 71–73, Mar. 1951.

Paper reports on two types of experiments. First type of test consists of carrying out repeated "hardness" tests on plasticine samples, which are loaded with a sphere indenter at a series of increasing loads. The yield values increase markedly.

The Meyer coefficient n is defined as the slope of the curve plotting $W/\log d$ where W is the load and d is the diameter of indent. Materials are sometimes considered to strain harden if $n > 2.0$. Authors report that by this definition plasticine certainly strain hardens as, in test results reported, n reaches an approximately constant high value of 3.5.

Second type of test is a constant-stress creep test in which sample is loaded with the sphere indenter and stress is defined as load/projected area of indentation. As indented area increases with time, load is also increased to keep stress approximately constant. In this case, Meyer coefficient $n < 2.0$, but the rate of increase of indentation certainly slows down as time goes on. This is perhaps another way of defining strain hardening. Plasticine shows some elastic recovery on removal of load.

Yoh-Han Pao, USA

3255. **Hsiao, C. C., and Sauer, J. A., On crazing of linear high polymers,** *J. appl. Phys.* **21,** 11, 1071–1083, Nov. 1950.

Effect of various variables, such as type of stress, stress magnitude, duration of stressing, and environment on initiation and development of crazing in linear polymers is discussed. Basic nature of crazing is investigated in some detail for polystyrene specimens by means of the light microscope, electron microscope and x-ray spectrometer. Results of these observations and their bearing on the fundamental group structure of polystyrene molecules is presented.

The relationship between crazing and orientation is discussed, as well as effect of both of these factors on the mechanical properties. Experimental results are compared, wherever possible, with previously reported data of other investigators. A short discussion is given of a theory of crazing from the point of view of molecular structure of the material. From authors' summary

3256. **Morlier, O. W., Orr, R. S., and Grant, J. N., The relation of length to other physical properties of cotton fibers,** *Text. Res. J.* **21,** 1, 6–13, Jan. 1951.

From data obtained from single-fiber studies of length groups

from American Upland cottons, following conclusions were drawn: (1) Average breaking load and average tenacity of single fibers increase with increasing fiber length within a sample. (2) Within a sample, weight fineness (taken on the center part of the fiber) reaches a maximum for fibers, length of which is near the modal length. (3) With increasing fiber length, elongation at break increases, ratio of elongation at break to breaking load decreases, and coefficients of variation for both breaking load and elongation at break decrease. (4) The finer varieties exhibit the greater average stiffness, or ratio of tenacity to strain. (5) A method is described for calculating a tenacity "index" for a cotton sample on the basis of single-fiber tests on only three length groups; this index shows a good correlation with the average single-fiber tenacity, which is calculated on the basis of all fibers in the sample.

From authors' summary

3257. Dollins, C. W., An investigation of creep, fracture, and bending of arsenical lead alloys for cable sheathing—Series 1949, *Univ. Ill. Engng. Exp. Sta. Bull.* **48,** 17, 59 pp., Oct. 1950.

Properties of lead and lead-alloy sheathing for underground power cable are given. Special emphasis is placed on the arsenical-lead alloys which have come into commercial use during the last few years. The data cover creep rates under steady tensile stresses up to 300 psi, time to fracture under steady stresses of 400 to 2000 psi, and number of cycles to fracture in slow bending.

Small amounts of arsenic in combination with other constituents and with proper production technique are shown to produce a marked improvement in all three of these properties. At the temperatures and stresses in normal service, reduction in creep rates from those of commercially pure lead is considerable. However, for some arsenical sheaths that have been produced, at the upper limits of 150 F and 200 psi, which might occur for some cables during emergency ampere-loading in service, creep resistances were little or no better than those of copper-bearing lead.

Arsenical-lead alloys have good ductility, as is shown by the elongations to fracture of strip specimens under steady tensile stress. As rate of strain is decreased with accompanying lengthening of time to fracture, for a number of tests the ductility decreases until a minimum is reached; then for still lower rates of strain the ductility increases. The larger the grain size, the lower the rate of strain or stress at which the minimum occurs. For alloys tested, the minimum points are well above range of stresses encountered by sheaths in service.

Arsenical-lead alloys have outstanding ability to withstand slow bending of type that occurs in service due to daily expansion and contraction of the cable. The magnitude of the improvement in this property as well as in other properties over the properties of copper-bearing lead has varied considerably, but some samples of arsenical lead sheaths have shown great improvements in overall properties. At small bending strains, the smaller-grain alloys give the better results; at larger bending strains, the larger-grain alloys give the better results.

Reliable indications of these various properties of cable sheathing of any type are obtainable only from long-time tests.

From author's summary

3258. Druyvesteyn, M. J., and Du Toit Meyer, M. A., Elastic moduli and hardness of some binary alloys (in Dutch), *Ingenieur* **62,** 46, Mk. 99–Mk. 104, Nov. 1950.

Experimental values found in the literature for the elastic moduli and hardness of binary alloys are discussed. In case of complete miscibility over the whole range of composition, elastic modulus is a linear function of composition, or in few cases somewhat higher than that found from this linear relationship. In this case hardness is often a quadratic function of composition. For two-phase alloys, elastic modulus and hardness vary linearly with composition. As a result of finite amount of each element dissolved in the other, elastic modulus is somewhat lower and hardness somewhat higher than a line joining values for the elements.

Elastic and hardness properties of Hume-Rothery alloys are also discussed. Experimental results can be explained in a qualitative way. From authors' summary

3259. Grobe, A. H., and Roberts, G. A., Mechanical properties of stainless steel powder, *J. Metals* **191,** 2, 125–130, Feb. 1951.

Former attempts to produce sintered 18-8 stainless steel gave insufficient mechanical properties of the sintered bodies due to the preponderance of spheroidal powder particles and their oxygen contents. Sinterings from realloyed powders with increased silicon contents of 2.5% gave better results; with a 100-mesh standard powder after pressing at 40 tons/sq in. and after sintering for 45 min at 2250 F, a tensile strength was obtained of 40,000 psi and an elongation of 15%; after coining at 40 tons/sq in. and resintering, 65,000 psi and 22% were obtained. Best values are 87,000 psi and 32%. Densities came near 7.0 g/cm³. Silicon promotes the formation of ferrite; the carbon contents were lowered by the hydrogen atmosphere at sintering below 0.02%. There is no information on the corrosion resistivity of the improved sintered alloys. Franz Wever, Germany

3260. Freas, A. D., Studies of the strength of glued laminated wood construction, *Amer. Soc. Test. Mat. Bull.* no. 170, 48–59, Dec. 1950.

Research, conducted for the purpose of providing information to be used in recommending design procedures for glued laminated wooden structural members, is described. This includes investigation of the influences of defects, design, and methods of fabrication on the strength of curved and straight wood laminates. The strength of curved members, tested under end thrust, is related to radius of curvature and percentage of defective material confined to interior laminae. The effects of type and location of end joints within a lamina and method of applying gluing pressure are defined. Glued laminates are compared with other types of curved members, and tests of building arches in place are described. In straight members, the thickness of laminae is reported to exert no influence on bending-strength properties. Properly designed scarf joints within laminae are shown to reduce bending-strength properties insignificantly, whereas laminae containing butt joints on the compression side of the neutral axis are considered ineffective areas in the beams, and those containing butt joints on the tension side are reported to reduce the strength more than would be estimated by considering the joint ineffective. Bending-strength values are related to the ratios of the moment of inertia of the part of the cross section occupied by knots to that of the entire cross section. Information concerning columns containing knots and joints is presented.

Stephen B. Preston, USA

3261. Perryman, E. C. W., Stress-corrosion of magnesium alloys, *J. Inst. Metals* **78,** part 6, 621–642, 1951.

Stress-corrosion properties of magnesium-5% aluminum alloy in distilled water and other solutions have been investigated. Stress-corrosion tests were also carried out on other commercial magnesium-base alloys and on high-purity magnesium.

Rapid transcrystalline cracking of stressed magnesium-5% aluminum alloy in distilled water took place, whether the alloy contained a precipitated second phase or not. This cracking bore no apparent relationship to the metallographic structure

following neither grain boundaries nor twin planes. Stress-corrosion was associated with a localized penetrative type of transcrystalline attack, which was never observed to be more than 2–3 grains deep. The stress-corrosion resistance decreased with increase in iron content and in amount of plastic deformation, but was improved by annealing at 200 C after plastic deformation. The presence of dissolved oxygen was found essential for stress-corrosion to operate; e.g., stressed loop specimens which failed in aerated distilled water in 10 days, did not crack in de-aerated water in 60 days. Transcrystalline stress-corrosion fractures occurred in saturated magnesium carbonate, 0.5% potassium fluoride, and 0.5% potassium hydrogen fluoride solutions, and in 0.5% hydrofluoric acid, and intercrystalline fractures in 0.05% potassium chromate solution.

The susceptibility to stress-corrosion failure of the various commercial alloys tested was consistent with their reported service behavior, the magnesium-manganese and magnesium-zinc-zirconium alloys being more resistant than the magnesium-aluminum alloys. All alloys tested and also high-purity magnesium suffered stress-corrosion cracking in 0.5% potassium hydrogen fluoride solution.

No detailed mechanism of stress-corrosion cracking in magnesium-base alloys is put forward, though the results show that the process is in part electrochemical. It is thought that cracking may be associated with minor impurities, e.g., iron, which are known to have a deleterious effect on the ordinary corrosion resistance. From author's summary

3262. **Hudson, J. C., Corrosion of bare iron or steel in sea water,** *J. Iron Steel Inst.* **166,** part 2, 123–136, Oct. 1950.

Presence of millscale on the iron or steel is shown to promote serious pitting in sea water. Rate of general corrosion of mild steel when immersed in British waters after removal of the millscale is found to be approximately 3–5 mils/yr. There is little, if any, difference in corrosion rates, under these conditions, of ordinary unalloyed ferrous materials such as mild steel, ingot iron, or wrought iron. Of a wide range of alloying elements incorporated in a series of low-alloy steels, only two, chromium and nickel, are shown to have any significant effect in reducing the corrosion rate. Steels containing 2–3% of chromium were found to corrode at one half or one third of the rate of unalloyed steels of the same carbon content. Effect of nickel additions was less marked. No significant difference has been observed in the behavior of ordinary and of copper-bearing steels when totally immersed in sea water. From author's summary

Mechanics of Forming and Cutting

(See also Revs. 3223, 3224, 3245)

3263. **Spencer, R. S., and Gilmore, G. D., Some flow phenomena in the injection molding of polystyrene,** *J. Colloid Sci.* **6,** 2, 118–132, Apr. 1951.

Steps in an injection molding cycle comprise dead time, filling, packing, discharge sealing, sealed cooling, and mold open time. Those steps involving polymer flow are discussed in this paper.

Filling time is directly proportional to the polymer melt viscosity, and inversely proportional to a power of the ram pressure. Raising the mold-wall temperature lowers the filling time. Reducing friction between the solid polymer and metal lowers the filling time, but only if the cylinder ahead of the heating chamber is cool. Studies with a glass-window mold show that hot polymer flows only in a central region, there being stationary layers next to the mold walls. When flowing polymer reaches the advancing front it contacts the mold wall, cools, and ceases flowing. In a typical case the thickness of the central region was 40% of the total thickness.

An approximate equation is presented for calculating maximum pressure in the mold during packing. Agreement with experimental values is good. Approximate treatment of sealing by "freezing" in the gate leads to a linear relationship between temperature and pressure in the mold at the sealing point.

From authors' summary

3264. **Tschirf, L., Contribution to the determination of the change in the axial thrust in lathes during straight turning** (in German), *Öst. Ing.-Arch.* **4,** 3–4, 256–270, 1950.

Under elastic conditions, a relationship is established between the axial cutting force, the workpiece holding forces, and the center-displacing forces in a lathe. This theory and experimental results show that during turning a workpiece in a lathe, the transverse cutting force does not necessarily increase the forces acting longitudinally to the lathe bed. Such an increase occurs only when the center-displacing forces exceed a certain maximal value derived in this article. It is thus observed that the formulas given in various handbooks for the computation of the axial forces in lathes are incorrect, as they do not consider this unique phenomenon. Dimitri Kececioglu, USA

3265. **Trigger, K. J., and Chao, B. T., An analytical evaluation of metal-cutting temperatures,** *Trans. Amer. Soc. mech. Engrs.* **73,** 1, 57–66, Jan. 1951.

It is well known that tool life and other performance factors in machining are profoundly influenced by the temperature at the chip-tool interface. In this paper, cutting-temperature equations are developed for direct calculation of this interface temperature, given the tool forces, cutting conditions, chip geometry, tool-chip contact area, and thermal properties of tool and work. The equations are developed by consideration of the heat generated by deformation of the metal on the shear plane in the process of chip formation, that generated at the chip-tool interface by rubbing friction, and the division of this heat between chip and tool at the interface. Calculated values of chip-tool interface temperature are compared with experimental values obtained by use of the tool-work thermocouple method. Reasonably good agreement is obtained for cutting speeds above 200 fpm and excellent agreement for speeds above 500 fpm. Results appear to be directly applicable to many actual machining operations, permitting calculation of actual interface temperatures.

M. Eugene Merchant, USA

3266. **Winzer, A., Solution to the rolling problem for a strain-hardening material by the method of discontinuities,** *J. appl. Mech.* **18,** 1, 90–94, Mar. 1951.

An approximate solution to the rolling problem for a strain-hardening material in plane strain is given. The roll is replaced by a polygonal wall. Deformation is assumed to occur across discontinuity surfaces; the material between these moves as a rigid whole. The tangential stress and velocity components are both allowed to be discontinuous across the surfaces. Relations are established from which the velocity and stress distributions along the wall and centerline are derived. A method is suggested for fitting the results to a given stress-strain curve.

This theory and the elementary theory of rolling (based on a uniform compression) differ by a few per cent. Since Hill (see AMR **4,** Rev. 2471] has shown that both the tangential stress and velocity components cannot be discontinuous across a discontinuity surface, it is doubtful whether the present theory improves on earlier work. J. F. W. Bishop, England

3267. Bergen, J. T., and Scott, G. W., Jr., Pressure distribution in the calendering of plastic materials, *J. appl. Mech.* **18,** 1, 101–106, Mar. 1951.

Pressure values and distribution were measured for calendering plastic materials by equipping a 10-in. calendering roll with a pressure-measuring cell. Pressures as a function of angular position were recorded photographically.

Experimental results were found to agree quite well with analytical expressions derived by Gaskell when the material had the properties of a viscous liquid. Commercial plastics were found to have properties perceptibly different from a viscous fluid. Test results are presented to show the effect of roll separation, roll speed, and presence of solid fillers.

William Schroeder, USA

3268. Baron, H. G., and Thompson, F. C., Friction in wire drawing, *J. Inst. Metals* **78,** part 4, 415–462, 1950.

Paper is an excellent example of the application of fundamental principles to a practical problem in plasticity. Authors are to be congratulated for effectively combining several fundamental concepts of the behavior of material, particularly the use of true stress-true strain with carefully obtained experimental data. The information on coefficient of friction is particularly useful for plasticity studies. While the paper deals with wire drawing primarily, the fundamental thinking involved is applicable to quite a number of other types of metal workings. R. G. Sturm, USA

Hydraulics; Cavitation; Transport

(See also Revs. 3293, 3315, 3375)

3269. Benini, G., On water hammer phenomena in conduits provided with a surge tank with throat (in Italian), *Energia elett.* **27,** 11–12, 682–694, Nov.-Dec. 1950.

Paper describes experiments in the Hydraulics Laboratory of Padua on a conduit provided with a surge tank with throat at the bottom. Two situations are considered, with different positions of the surge tank along the conduit. The diagrams of the pressures at the foot of the surge tank and near the obturator were determined for different types of closures. Some of those diagrams are compared with the analogous one obtained by graphical calculation (Bergeron's method) and a good agreement is found. For some cases, a simple analytical solution was given also, deriving from the same method. Some details of the experimental setup are interesting. Duilio Citrini, Italy

3270. Silber, R., Study of flow in open channels (in French), *Houille blanche* **5,** no. B, 662–673, Nov. 1950.

The equation between depth and output of a slowly changing open channel flow is put into a standard form ($q^* = y^*(1 - y^*)^{1/2}$) through the introduction of a nondimensional depth and output, y^* and q^*. These quantities are nondimensionalized in terms of the specific head, the difference between total head and relative height of each section. Since in ideal channel flow the specific head remains constant, the flow is obtained by means of a simple procedure using the y^*, q^* characteristic. To obtain the flow for prismatic and nonprismatic channels, an iterative finite difference and geometrical method is applied to a set of y^*, q^* characteristics. However, the same characteristics are applicable for all channels. Peter Chiarulli, USA

3271. Donoghue, J. J., Vollrath, R. E., and Gerjuoy, E., The tensile strength of benzene, *J. chem. Phys.* **19,** 1, 55–61, Jan. 1951.

Authors attempt to measure tensile strength of benzene in glass tubes by centrifuge method. They fare little better than previous investigators in that the strength measurements are not reproducible; test results even with the same glass tube differ by factors of 2 to 4. The highest measurement gave rupture strength of 157 atm. Arguments are presented concerning reasons for extreme variabilities; authors consider the history of the glass tubes used in centrifuging to be very important, increasing exposure of tubes to atmosphere decreasing tensile strengths observed. There is also evidence that decrease of permanent gas content increases strength.

Authors present an interesting, highly refined technique, but it is disappointing that results are not more conclusive.

B. W. Augenstein, USA

3272. Bogardi, J., Solid transportation by rivers with special reference to measurements made in Hungary (in French and English), *Houille blanche,* **6, 2,** 108–126, 127–131, Mar.-Apr. 1951.

Article reviews briefly investigations in the field of transport of solid matter in rivers. Theories of critical tractive force and critical velocity are stated to be unsatisfactory as criteria for initiation of movement. As a result of experiments at Iowa Institute of Hydraulic Research, author claims that the critical bed velocity should be considered as the parameter for this purpose. He does not mention more rigorous results obtained by Shields, White, Kalinske and others who made an attempt to analyze the forces acting on a particle in terms of the liquid shear stress at the bed, and the variations in shear due to turbulence which are of more direct significance in the starting of movement [see reviewer's paper in *Ann. Trav. publics Belg.* 1, 2, 3, 1948]. For the solid discharge, author does not set forth the results of formulas and laboratory tests, but mentions the field methods of measuring the bed load and gives a short description of several types of samplers devised in Hungary. After a review of the theoretical investigations on suspended load (simple lift theory, turbulent mixing theory) author describes briefly the silt samplers used for field tests in his country. Finally he works out a formula for total suspended load in terms of the hydraulic characteristics with application to Hungarian rivers. Article closes with the relationship between the solids carried along the river bed and the material which forms the bed itself; a formula is worked out for use in river regulation design which enables finding the width of rivers by a given slope and grain size of the bed material.

G. A. T. Heyndrickx, Belgium

3273. Poggi, B., On the equilibrium velocity of bodies immersed in an ascendent vertical flow (in Italian), *Energia elett.* **28,** 2, 87–92, Feb. 1951.

Terminal velocities reported for spheric and disk forms of river gravel (diameters less than 50 mm). M. J. Goglia, USA

3274. Eisenschitz, R., Recent theories of transport processes in liquids, *Nature* **167,** 4241, 216–220, Feb. 1951.

Problems, methods, and achievements of recent theoretical work using the kinetic theory of liquids to explain irreversible processes are reviewed. Momentum and energy flow, viscosity, thermal conductivity, and diffusion are considered. Certain arguments in sections on the hypothesis of molecular chaos and on frictional force are from unpublished work. Highly theoretical.

Stacey G. Ward, England

3275. Craven, P. M., and Lambert, J. D., The viscosities of organic vapours, *Proc. roy. Soc. Lond. Ser. A,* **205,** 1082, 439–449, Feb. 1951.

The viscosities of the vapors of ethane, n-hexane, cyclohexane, benzene, methyl chloride, ethyl chloride, methyl alcohol, diethyl ether, acetaldehyde, acetone, and acetonitrile have been measured

at temperatures 35, 50, 65, and 78 C and pressures between 1 and 3 cm. Measurements were made by observing the damping of a pendulum swinging in the vapor. A linear relation between coefficient of viscosity and temperature was found in all cases. The ratios of thermal conductivity to viscosity were calculated, using thermal conductivity values obtained recently in the same temperature range. The observed values of the Eucken factor for nonpolar vapors show systematic positive deviations from the theoretical values; strongly polar vapors show systematic negative deviations; weakly polar vapors show intermediate behavior. The theoretical implications of these phenomena are discussed.
From authors' summary

3276. **Sverdrup, N. M., Kinematic viscosity curves of hydraulic fluids,** *Prod. Engng.* **22,** 4, p. 173, Apr. 1951.

3277. **Sverdrup, N. M., Calculating the energy losses in hydraulic systems,** *Prod. Engng.* **22,** 4, 146–152, Apr. 1951.

Paper gives graphical methods of analyses that save time and make tedious mathematical calculations unnecessary. Charts for frictional and energy loss coefficients in AN hydraulic fittings, circular pipes, and other elements used in hyraulic circuits are included. From author's summary

Incompressible Flow: Laminar; Viscous

(See also Revs. 3270, 3335, 3365, 3432)

3278. **Laitone, E. V., Experimental measurement of incompressible flow along a cylinder with a conical nose,** *J. appl. Phys.* **22,** 1, 63–64, Jan. 1951.

A 12-in. long cylindrical body of 4-in. diam with a 20- or 30-degree conical nose is tested at a Mach number of 0.1 and a Reynolds number of 250,000 based on the 4-in. diam. In both cases the measured pressure distributions are compared with author's theory, giving excellent agreement for each of the cylindrical after-bodies, and for the smaller of the conical noses.
Fritz W. Riegels, Germany

3279. **Rouse, H., and Abul-Fetouh, A.-H., Characteristics of irrotational flow through axially symmetric orifices,** *J. appl. Mech.* **17,** 4, 421–426, Dec. 1950.

Although an exact analytical solution of the orifice problem has not yet proved feasible, use of the relaxation method has permitted a numerical determination of flow characteristics to be made with sufficient precision for the problem to be considered solved. The coefficient of contraction is found to be practically identical with that evaluated by von Mises for two-dimensional flow from slots over the entire range of area ratio, and reasonable agreement is shown to exist between measurement and computation. Coordinates of the jet profiles are presented in tabular and graphical form, and are found to differ appreciably from those previously adapted from the two-dimensional case. A composite dimensionless chart is also provided showing the distribution of pressure along the boundary and center line and across the efflux section for the various area ratios.
From authors' summary by H. A. Einstein, USA

3280. **Fabri, J., and Siestrunck, R., On periodic-axial machines** (in French), *C. R. Acad. Sci. Paris* **231, 2,** 115–117, July 1950.

Authors give concise information concerning investigations they have carried out on periodic-axial machines. The basic assumptions of these investigations are: Incompressible fluid; either fixed or movable wheels with infinite blade number; and cylindrical stream surface. Setting the condition that the flow is identical in every stage, they deduce the usual properties of the periodic flow, as well as the radial distribution of the axial component of the velocity. Finally, authors investigate the stability of the above-mentioned periodic flow. Carlo Ferrari, Italy

3281. **Rose, A., On the use of a complex (quaternion) velocity potential in three dimensions,** *Comment. math. helvet.* **24,** 135–148, 1950.

Paper approaches axially symmetric flows by a method paralleling complex function theory in the hydrodynamics of plane flows; it uses as the appropriate tool the theory of analytic functions of a quaternion [see Fueter, title source, **7,** 307–330, 1935]. For a given flow the author defines a new stream function $\psi(x, y, z, \xi, \eta, \zeta)$ of the pair of points $A(x, y, z)$, $B(x + \xi, y + \eta, z + \zeta)$ to be the rate of flow of fluid across the plane triangle formed by these two points and the origin (the sign of ψ being based on a suitable convention). If the fluid is incompressible and the flow axially symmetric and irrotational, with φ the potential, and if we define $(\psi_1, \psi_2, \psi_3) = (\partial\psi/\partial\xi, \partial\psi/\partial\eta, \partial\psi/\partial\zeta)_{\xi,\eta,\zeta=0}$, then the quaternion function $\varphi + i\psi_1 + j\psi_2 + k\psi_3$ satisfies the conditions for it to be a right-regular function of the quaternion $w + ix + jy + kz$, where i, j, k are the usual quaternion units and w is an imaginary fourth coordinate whose axis is perpendicular to the other three. Thus the theory of analytic quaternion functions is in principle applicable. Author considers examples of several specific flows for which he determines the stream function explicitly, and, in particular, he finds the complex quaternion potential for the uniform flow past a sphere by a method entirely analogous to the complex variable method for the cylinder.
Courtesy of Mathematical Reviews D. Gilbarg, USA

3282. **Couchet, G., Additional remarks on plane motion with constant circulation** (in French), *C. R. Acad. Sci. Paris* **231,** 2, 112–114, July 1950.

In an earlier note [same C. R. 221, 280–282, 1945], author has considered those problems of two-dimensional nonuniform motion of airfoils in incompressible fluids for which the circulation around the airfoil remains constant. In the present note he gives, without proof, formulas concerning the effect of a finite number of free concentrated vortexes in the flow field. E. Reissner, USA

3283. **Al'tshul', A. D., On the turbulent motion of fluids in smooth pipes** (in Russian), *Dokladi Akad. Nauk SSSR,* **75,** 5, 617–620, Dec. 1950.

Using experimental data of Nikuradse [*Ver. dtsch. Ing., Forschungsheft* **356,** 1932], it is shown that there is a linear relation between the turbulent velocity at a distance y from the wall of a circular tube of radius r and $\ln(Re \cdot y/r)$ for Reynolds numbers between 4000 and 3,240,000. This is shown to be in agreement with an assumption of Zhukovski that the thickness of the boundary layer in a tube should be inversely proportional to the flow velocity. D. Ter Harr, Scotland

3284. **Špaček, L., Laminar flow in a partially-filled pipe of circular cross section,** *Engng. Rev. Prague,* no. 1, 19–28, Feb. 1950.

Quantity of flow through a sloping pipe is obtained by solving Navier-Stokes equations for velocity distribution over pipe cross section and then integrating over filled portion of cross section. The flow is fully developed. Problem of finding velocity distribution is reduced to solving Laplace's equation with boundary conditions of present problem. Result obtained shows that maximum rate of flow occurs when about 85% of vertical pipe

diameter is submerged. Maximum rate of flow is about 27% greater than when the pipe is completely filled.

Neal Tetervin, USA

3285. Konstantinov, V. A., Influence of Reynolds number on the separation (cavitation) flow, *David W. Taylor Mod. Basin Transl.* 233, 20 pp., Nov. 1950.

With very simple laboratory equipment, author measures the pressure distribution on a series of cylinders from 5 to 50 mm in diameter at Reynolds numbers from approximately 27,000 to 450,000. Integration of these pressures over the surface of the cylinders yields resistance coefficients C_x which, when compared, indicate that three definite regions defining the flow can be set up. The subcritical region shows C_x as entirely dependent on R; the supercritical region shows C_x as independent of R; and the critical region defines when a flow of separation occurs. Although explanations for these flow characteristics are made, author cautions that air content in the water, which was not checked, may have influenced the results and that checks should be made in future work of this kind. Robert S. Ross, USA

3286. Levine, J., Statistical explanation of spontaneous freezing of water droplets, *Nat. adv. Comm. Aero. tech. Note* 2234, 27 pp., Dec. 1950.

Study of supercooling and subsequent freezing of water droplets has been stimulated because airplanes ice up when flying through clouds of supercooled droplets. Author derives frequency-distribution curves for spontaneous freezing temperatures of supercooled droplets on the following basis: (1) Various motes, or points at which freezing starts, become active at different temperatures. (2) The volumetric density of motes active within a specified narrow temperature range increases geometrically as the average temperature of that range decreases. (3) Water droplets can be so small that most of them are free from randomly distributed motes of high activity but low average density. Such drops may be supercooled to the various temperatures at which their most active motes become effective. (4) Water droplets withdrawn for study from a vapor supply are only an infinitesimal fraction of the supply.

Experimental studies of freezing of drops condensed on surfaces have been made by others [Dorsch, R. G., and Hacker, P. T., AMR **4**, Rev. 2102]. Adjustment of constants in mathematical expressions, derived here to fit the experimental freezing temperature-drop size relationship, gives theoretical freezing ranges much narrower than those observed experimentally.

The mote hypothesis implies impurities. However, the derivation is valid for spontaneous development of crystals in pure liquid, provided a time factor is added. Experimental results obtained by others had indicated the absence of a time factor [Dorsey, N. E., *Trans. Amer. phil. Soc.* **38** (M5), 247–326, Nov. 1948]. Present theory shows that this finding could be due to the limited range of experimental conditions.

Theory should be applicable to supercooled clouds and indicates that such clouds do not have definite freezing points but are unlikely to exist below −35 C. Author recognizes need for experimental study of effects of finely divided additives and of special cleanliness, and also of drops suspended in air rather than condensed on surfaces.

Reviewer notes that the freezing of water droplets is one example of crystallization and, as such, is allied to vitrification of glass, crystallization of sugar, behavior of heat-treated metals, etc. As the author appears to realize, both spontaneous and impurity-induced freezing should occur. In the former process, not only mote density but rate of growth must be important. Although the specific assumption of a geometric mote density-freezing temperature relationship seems unsatisfactory, the basic idea merits further study. J. D. Bush, USA

3287. Ghetti, A., Velocity distribution inside and shear stresses around a steady flow (in Italian), *Energia elett.* **27,** 11–12, 664–681, Nov.-Dec. 1950.

The velocity distribution in a cross section and the distribution of the shear stress at the periphery for study of laminar and turbulent flows are investigated. The practical solution of problems for some arbitrary cross sections is demonstrated in the case of the laminar flow by extending by analogy the methods of the theory of elasticity. In the case of turbulent flow, recognizing the lack of an adequate basic theory, various hypotheses proposed for the interpretation of the scarce experimental data available are re-examined. A restriction upon the basic variables, which are shown to permit the solution in the laminar region, and a systematic series of expressions are proposed whence solutions of practical interest in the turbulent region are initiated.

From author's summary by M. J. Goglia, USA

3288. Berker, R., On certain properties of the force exerted on a wall in contact with a viscous fluid (in French), *C. R. Acad. Sci. Paris* **232,** 2, 148–149, Jan. 1951.

For viscous flow past wall S, author finds force on wall is as follows: Incompressible flow, normal component equals pressure p, tangential component, 2μ times vorticity vector turned through 90° in tangent plane in obvious sense; compressible flow, normal component modified by addition of $-(4/3)\mu\theta$. Results follow from

$$\vec{n}\cdot\nabla\vec{V} + n\Lambda \text{ rot. } \vec{V} - \vec{n}\cdot\text{div } \vec{V} = 0$$

(use Stokes formula) and

$$\vec{E} = p\cdot\vec{n} - 2\mu\vec{n}\cdot\nabla\vec{V} - 2\mu(\vec{n}\Lambda\vec{\omega}),$$

where $\vec{n}$ is unit normal to S; $\vec{V}$, velocity vector; E, force; p, pressure; $\vec{\omega}$, vorticity vector; $\theta = \text{div } \vec{V}$.

Morton Finston, USA

3289. Dean, W. R., Slow motion of viscous liquid in a semi-infinite channel, *Proc. Camb. phil. Soc.* **47,** part 1, 127–141, Jan. 1951.

The stream function ψ for this slow, steady plane viscous flow through the "Borda's mouthpiece" is to satisfy the biharmonic equation in the whole x, y plane and $\psi = \pm 1$, $\partial\psi/\partial n = 0$ on both sides of the semi-infinite channel partitions $y = \pm 1$, $x > 0$. The problem is made determinate by prescribing that the flow approach the Poiseuille flow as $x \to \infty$ inside the channel, and the source flow as $r \to \infty$ outside the channel. A biharmonic function ψ_1 having approximately this asymptotic behavior and satisfying $\psi_1 = \pm 1$ on channel walls is constructed by "feel." A second biharmonic function ψ_2 involving 16 undetermined constants and satisfying $\psi_2 = 0$ on $y = \pm 1$, $x > 0$, is similarly devised. The condition $\partial(\psi_1 + \psi_2)/\partial n = 0$ on channel walls is satisfied approximately by minimizing the sum of the squares of the slip velocities at 16 boundary points by proper choice of the 16 constants. Accuracy of the solution, as judged by the magnitude of the slip velocities, was poor until a more general ψ_1 with two free constants was assumed. The actual work is in half plane obtained from the physical plane by the conformal mapping $\pi z = \zeta^2 - 2\log\zeta - 1 + 1\pi$.

The complete solution is examined at ∞ inside and outside of channel, and at edges of the mouth. From approximations up to third order of the distance from the edge it is concluded that "the

liquid leaves the mouth of the channel in a jet of angle 51° 52′ with symmetrical back waters on each side." Author does not discuss how this singularity is affected by the lack of generality of the assumed form of solution, or to what extent the assumption of slow motion near the mouth is warranted. The pressure variation along the channel center is found to approach the Poiseuille slope rapidly, with a slight "lag" interpreted as edge effect.

Mark V. Morkovin, USA

3290. **Davies, D. R., A note on Rayleigh's problem for a plate of finite width,** *Proc. Camb. phil. Soc.* **47,** part 1, 248–250, Jan. 1951.

It is shown that the viscous motion of an infinite plate of finite width, set into uniform motion parallel to the edges, satisfies the same equation and boundary conditions as the problem of evaporation from a rectangular lake into a turbulent airstream with constant speed and eddy diffusivity [AMR **4**, Rev. 1847]. General solutions await the complete tabulation of Mathieu functions. A special solution, however, obtained by Howarth [AMR **3**, Rev. 1973] for the semi-infinite flat-plate problem may be applied to the problem of evaporation from an infinite quadrant.

Walter Wuest, Germany

3291. **Arzhaníkh, I. S., The integral equations of steady motion of a viscous incompressible fluid** (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)*, **74,** 1, 21–24, Sept. 1950.

Author considers the following two problems for viscous incompressible fluids: (1) Motion of a fluid inside a closed rigid container rotating with constant angular velocity; (2) motion of a fluid outside a rigid body moving with constant velocity, the fluid being at rest at infinity. Author shows that the absolute velocity and the pressure can be expressed in terms of quantities determined by seven (two vectors and a scalar) integral equations which are nonlinear inasmuch as the vector product of the two unknown vector functions enters. Simplifications for slow motion and the possibility of solving the equations by a series expansion are discussed briefly.

J. V. Wehausen, USA

3292. **Golitzine, N., Sharp, C. R., and Badham, L. G., Spray nozzles for the simulation of cloud conditions in icing tests of jet engines,** *Nat. Res. Counc. Canad. mech. Engng. Rep.* ME-186, 11 pp., Aug. 1950.

Paper describes development of nozzles for production of water droplets 5 to 50 microns in diameter, corresponding to conditions in natural icing clouds. Atomization was produced by introduction of water at center of a high velocity airstream in an orifice. Tests indicated that droplet size is dependent primarily upon water-to-air-mass-flow ratio for air pressures above critical, increasing with this ratio. Effect of increasing nozzle size is to give coarser atomization. Convergent nozzles were found to give finer particles than divergent nozzles. Comparison of drop-size distribution with natural cloud samples gave good agreement.

Minimum median drop diameter obtainable with swirl-type nozzles was found to be 35 microns.

A. Shaffer, USA

3293. **Hinze, J. O., Atomization of liquids by means of a rotating cup,** *J. appl. Mech.* **17,** 2, 145–153, June 1950.

This theoretical and experimental analysis of liquid atomization by means of a rotating cup fills a need for information on an important subject. Authors have correlated the important factors involved and obtained workable relationships. Problem dealt with concerns the disintegration of a liquid fed through a stationary tube to the inner surface of a rotating cup which widens to a brim. The film on the inner surface has been found to flow viscously. Authors have determined the thickness of this film in terms of readily measured constants. The nature of the disintegration phenomenon itself has been carefully studied, and three types have been noted: (1) Direct drop formation; (2) ligament formation and eventual disintegration; and (3) film formation at the cup brim. Causes of these types of disintegration are discussed at length. Relationships between the various states of disintegration are presented in graphs using experimental data, and the critical transition formulas are included. Droplet size of the mist produced was found to conform with the Rosin-Rammler distribution function.

Article contains an excellent account of "ligament" formation. Excellent photographs illustrate the various states of disintegration.

J. M. DallaValle, USA

Compressible Flow, Gas Dynamics

(See also Revs. 3281, 3334, 3338, 3339, 3349, 3362, 3368, 3389, 3409)

3294. **Harmon, S. M., Correspondence flows for wings in linearized potential fields at subsonic and supersonic speeds,** *Nat. adv. Comm. Aero. tech. Note* 2303, 29 pp., Mar. 1951.

Method is presented for obtaining solutions to a larger class of boundary-value problems from known solutions of simpler boundary-value problems. It is shown how the solution for the flow fields due to an arbitrary prescribed velocity distribution on a wing in supersonic or subsonic flow may be expressed in terms of the flow fields due to a uniform prescribed velocity distribution on a wing. Several simple correspondence formulas are obtained in this way for a rectangular wing.

Seymour Lampert, USA

3295. **Ackeret, J., Degen, M., and Rott, N., Pressure distribution over bodies of revolution at supersonic flow and oblique angle of incidence** (in German), *Termotecnica* **5,** 1, 11–19, Jan. 1951.

For slender bodies with an angle of attack, the cross flow can be approximated for each section of the body as two-dimensional. This yields simple expressions for the lift and the pressures. Paper presents an experimental check for subsonic Mach numbers. If one includes some nonlinear terms in the formulas for the pressures, the agreement between experiments and theory is very good. The influence of the boundary on the rear part of the body seems to cause more serious deviations than the inaccuracy of the linearized approach. Some remarks on the application of this idea to more general slender bodies are made.

Gottfried Guderley, USA

3296. **Karpovich, E. A., and Frankl, F. I., Resistance of a delta wing in a supersonic flow** (Transl. from Russian), *Nat. adv. Comm. Aero. tech. Memo.* 1283, 6 pp., Apr. 1951.

See AMR **1,** Rev. 901.

3297. **Wu, Chung-Hua, A general through-flow theory of fluid flow with subsonic or supersonic velocity in turbomachines of arbitrary hub and casing shapes,** *Nat. adv. Comm. Aero. tech. Note* 2302, 40 pp., Mar. 1951.

General equations for flow of a perfect fluid through a turbomachine are written and are reduced for the case of thin blades of high solidity to a reasonably simple partial differential equation. This equation is elliptic for subsonic axial velocity and hyperbolic for supersonic axial velocity. Methods of solving these two cases are discussed. The general equation is then specialized to the appropriate form for application to a free vortex design, a symmetrical velocity diagram, an untwisted blade design, and a

radial blade-element design. A method of correcting for finite blade thickness is mentioned. No actual solutions are presented. This work is a suitable starting point for detailed solutions which are required before comparison with experimental result is possible. Howard W. Emmons, USA

3298. Liepman, H. W., and Bryson, A. E., Jr., Transonic flow past wedge sections, *J. aero. Sci.* **17,** 12, 745–755, Dec. 1950.

Paper discusses two-dimensional flow about a simple wedge followed by a constant thickness section and compares some experimental results with the theoretical work of von Kármán, Guderley, Vincenti, and Cole. The experimental data were obtained in a 4 × 10-in. tunnel on three 0.25-in. models having wedge semiangles of 4.5°, 7.5°, and 10° and were taken from interferometer pictures, examples of which are shown for both the infinite fringe and the finite fringe techniques.

An interesting discussion is given on some characteristic features of the flow. It is shown that the local Mach number just ahead of the shoulder corner is sonic up to a Mach number at which sonic velocity exists following the attached shock. For a detached shock condition, if sonic velocity existed ahead of this shoulder, then supersonic flow would exist at the shoulder and would, therefore, prevent the shoulder from influencing the shock position. Since the shoulder is the only characteristic length of the wedge, it must influence the position of the shock and thus the sonic point cannot be ahead of the shoulder. It is also shown that the local Mach number distribution over the wedge is independent of the stream Mach number near a value of $M = 1$. This arises from the fact that the Mach number following the detached shock is as much below $M = 1$ as the free stream is above $M = 1$. The experimental data indicate that this independence exists over the rather wide range from $M = 0.8$ to $M = 1.2$. Above considerations give rise to the fact that near a value of $M = 1$, the increase in drag on the forebody of the wedge with Mach number is due only to the increase in static pressure across the detached shock. H. Hoadley, USA

3299. Guderley, G., and Yoshihara, H., The flow over a wedge profile at Mach number 1, *J. aero. Sci.* **17,** 11, 723–735, Nov. 1950.

Subsonic portion of the flow field past a symmetrically placed, double-wedge-shaped profile at free-stream Mach number 1 is studied in the hodograph plane (η, θ) with the variables reduced in accord with the Kármán transonic similarity law. There, problem amounts to finding a solution of the Tricomi equation $\varphi_{\eta\eta} - \eta\varphi_{\theta\theta} = 0$ for the disturbance potential with φ_θ vanishing on $\theta = 0$ and $\theta = \theta_0$ (for $\eta < 0$), and on the characteristic through $(0, \theta_0)$ (this line is the image of the wedge's convex corner). The portion of this characteristic between $(0, \theta_0)$ and $(\eta_0, \theta_0/2)$ (where the other characteristic from the origin cuts it) influences conditions on the sonic boundary. An equivalent boundary-value problem is shown to be $\varphi_\theta = 0$ on $\theta = 0$ $(\eta < 0)$ and on $\theta = \theta_0 (\eta < \eta_0)$, and $\varphi_\theta = \varphi_\eta = 0$ on $\eta = \eta_0 (\theta_0 \geqslant \theta \geqslant \theta_0/2)$.

A particular solution, suitably singular at the origin, is $\varphi = (1/\eta)F(1/3, 2/3, 3/2, 1 - \theta^2/\eta^3)$. Boundary conditions at $\theta = 0$ and $\theta = \theta_0$ are satisfied by placing images at $(0, 2n\theta_0)$ (n an integer) and adding. The conditions on $\eta = \eta_0$, $(\theta_0/2 \leqslant \theta \leqslant \theta_0)$, are adjusted by adding a suitable combination φ_3 of the analytically continued, particular solutions

$$g = i^{4/3}(|\eta|)^{1/2}H_{1/3}^{(1)}[2/3(m\pi/\theta_0)i|\eta|^{3/2}] \cos (m\pi\theta/\theta_0), \quad (\eta < 0)$$

(m a positive integer) which satisfy conditions on $\theta = 0$ and $\theta = \theta_0$ automatically.

There results a simple integral equation for $\varphi_{3\theta}$ $(0 \leqslant \theta \leqslant \theta_0/2)$ which can be solved by a Fourier expansion. The flow over the rear portion is computed by the method of characteristics. Drag coefficients are evaluated for diamond-shaped profiles and also for the case where the rear portion is shaped to give minimum drag. For 10% thickness placed at the optimum position (54% chord), the drag coefficient is 0.085, which is slightly higher than the previously studied, cusped nose profile.

A. F. Pillow, Australia

3300. Munk, M. M., The Rankine gas flow in the hodograph plane, *Quart. appl. Math.* **8,** 4, 387–392, Jan. 1951.

Paper provides compressible analog to incompressible Rankine flow, i.e., superposition of uniform stream and point source. Method involves use of Legendre hodograph transformation and solution is given in terms of hypergeometric series. Asymptotic behavior of solutions is investigated. Similarity of asymptotic solutions to solutions of Laplace's equation indicates compressible flow may be derived directly from corresponding series for incompressible hodograph solution. Rankine gas flow found has constant, parallel velocity at infinity, and contains a single point source. Work is similar to that of Cherry [AMR **1,** Rev. 870] and of Manwell [*Phil. Mag.* (7) **36,** 499–510, 1945]. A discussion on convergence of the series solution is given by A. Van Tuyl.

H. G. Cohen, USA

3301. Spooner, R. B., Effect of heat-capacity lag on a variety of turbine nozzle flow processes, *Nat. adv. Comm. Aero. tech. Note* 2193, 24 pp., Oct. 1950.

Computations of a number of turbine-nozzle flow processes including the effects of variable heat capacity and heat-capacity lag, were made and the results compared with those obtained from similar computations based on the assumptions of equilibrium expansion and of frozen vibrational energy.

The effect of heat-capacity lag on turbine-nozzle expansion processes in current turbojet engines is small, but it is more closely approximated by a condition of frozen vibrational energy (ratio of specific heats of 1.4) than by the equilibrium variable heat capacity. Calculation for a single set of flow conditions in a ramjet exhaust nozzle showed, however, that the actual flow process is more closely approximated by the equilibrium variable heat capacity for this case.

From author's abstract by Simon Ostrach, USA

3302. Cohen, C. B., and Evans, P. J., Jr., Note on desirability of completely expanded nozzles, *J. aero. Sci.* **17,** 12, 811–812, Dec. 1950.

Comments on paper by F. P. Durham [AMR **4,** Rev. 869]. Authors question Durham's conclusion that, up to pressure ratios of about 5 or 6, higher thrust is obtained by omitting diverging section of propulsion nozzle, and make calculations, based on what they consider more reasonable losses in this section, indicating that limiting pressure ratio is about 2 or 3. Calculations also indicate maximum thrust probably obtained vith diverging section theoretically suited to some pressure ratio less than actual ratio. In reviewer's opinion, all such calculations are subject to high probable error, and question should be settled by test if operating pressure ratios become much higher than critical.

C. W. Smith, USA

3303. Lampert, S., Conical flow methods applied to uniformly loaded wings in subsonic flow, *J. aero. Sci.* **18,** 2, 107–114, 138, Feb. 1951.

Report presents linearized thin-airfoil solutions for the twist and camber of wing plan forms supporting a uniform loading. Results correspond to the direct problem of integrating a given linear distribution of doublets over the plane of the wing. The

method, which is an adaptation of conical flow techniques introduced into supersonic flow studies by Busemann, would appear to be of principal interest in the possibility of its adaptation to the difficult indirect (integral equation) problems in subsonic flow.

Harvard Lomax, USA

3304. **Ribner, H. S., Damping in roll of cruciform and some related delta wings at supersonic speeds,** *Nat. adv. Comm. Aero. tech. Note* 2285, 43 pp., Feb. 1951.

Linearized calculation of aerodynamic forces on a cruciform wing in supersonic flow for rotation about the axis. For low aspect ratio (triangular panels very slender), the local potential in a section perpendicular to the axis is found from two-dimensional results for a wing with an arbitrary number of panels, and nondimensional damping-in-roll derivative is calculated.

In the case of a cruciform wing with supersonic leading edges, the symmetry of the problem requires solution of a boundary-value problem in a single quadrant, which can be dissolved into two simpler problems for delta wings. These solutions are well-known, and velocity and pressure distribution for the cruciform wing can be found by superposition.

In the case of subsonic leading edges, an exact solution for the boundary-value problem for one quadrant is not obtained, but an iteration procedure is introduced, satisfying, at first, boundary conditions for the velocity on the blades of the wing and violating the condition of vanishing pressure difference outside the wing and inside the Mach cone. Correcting for this condition, an additional term in the potential is obtained, which violates the original boundary condition on the wing and a new correction term is obtained.

The solutions for these partial problems are obtained by means of elliptic functions from known solutions for problems of plane flow, in particular, the linear delta wing with linear twist with subsonic leading edges.

The second iteration step (correction for the nonvanishing pressure difference in the plane of the blade outside the blade and inside the Mach cone) is not performed in an exact way, but an approximation is found.

Finally, for different positions of the outer edge of the wing, values of the nondimensional damping-in-roll coefficient are obtained with an estimated error of about 1%.

R. Timman, Holland

3305. **Carter, A. D. S., The low speed performance of related aerofoils in cascade,** *Aero. Res. Counc. Lond. curr. Pap.* 29, 20 pp., Sept. 1949, published 1950.

Report contains a general analysis of some test results on compressor and turbine cascades. It is shown that both these types of cascades can be treated in a similar manner, and data are given from which the performance of any cascade of the related series of airfoils considered can easily be calculated. An attempt has been made to explain variations in behavior of cascades, and, appreciating the factors involved, a fair idea of the performance of other airfoil sections can be obtained.

From author's summary

3306. **Lomax, H., Heaslet, M. A., and Fuller, F. B., Three-dimensional, unsteady-lift problems in high-speed flight—basic concepts,** *Nat. adv. Comm. Aero. tech. Note* 2256, 39 pp., Dec. 1950.

This note contains a treatment of thin wing theory on the basis of acoustics. Solution to the wave equation when the disturbances lie in a plane is represented by Kirchhoff's formula. The concepts of domain of dependence and region of influence are explained. A discussion of homogeneous boundary-value problems shows that, if the boundary values are homogeneous, the velocity potential $\varphi = t^n\varphi_0(x/t,y/t,z/t)$, where φ_0 satisfies an elliptic differential equation in a certain sphere. (This equation cannot be reduced to Laplace's equation.) Authors show that for wings with non-interacting edges in supersonic unsteady motion, results for lift analogous to steady motion are easily obtained. Various limiting cases, two-dimensional wings, slender wings, and simple examples, impulsive starting pressure, and the flow fields due to certain vortexes are worked out. No really new results are covered, but reviewer believes paper provides useful introduction to subject. Julian D. Cole, USA

3307. **Krzywoblocki, M. Z., On the asymptotic expansion in three-dimensional compressible viscous flow,** *J. Franklin Inst.* 250, 3, 213–217, Sept. 1950.

An exact solution of the set of equations (of motion, energy, continuity, and state) of a three-dimensional flow of a compressible viscous fluid (in which pressure, density, coefficients of viscosity, and heat conductivity are functions of position) represents insurmountable difficulties and cannot be achieved. Consequently, only approximation methods may be considered. Goldstein proposed an asymptotic expansion for the two-dimensional steady flow of an incompressible viscous fluid behind a solid body by means of exponential functions. That type of expansion was applied by author to a few cases of a two-dimensional steady flow of a compressible viscous flow. In present paper, author extends this method to a case of a three-dimensional flow of a compressible fluid. Not to obscure the problem by many items of a simple algebraic nature, paper presents only a general outline of the method of attack, applied to the simplest possible case; that is, to a flow along a yawed flat plate whose plane is parallel to the direction of the undisturbed flow. From two requirements, namely, (a) to solve exactly or approximately the equations, (b) to satisfy exactly or approximately the boundary conditions, in a case of a compressible viscous fluid (when no use is made of velocity potential or stream functions), it is possible to satisfy the requirement (a) approximately and (b) exactly. Author shows this in present as well as in previous papers. Presented method may be adjusted easily to three-dimensional wakes and jets as it was done in plane flows. From author's summary

3308. **Wang, Chi-Teh, Two-dimensional subsonic compressible flows past arbitrary bodies by the variational method,** *Nat. adv. Comm. Aero. tech. Note* 2326, 73 pp., Mar. 1951.

A variational principle for subsonic irrotational compressible fluid flow is established and approximate solutions of two flow problems are calculated by the Rayleigh-Ritz method. Solutions for flow past a circular cylinder without circulation and for flow past a thick curved surface agree fairly well with results obtained by the Rayleigh-Janzen and Kaplan methods, respectively. A value of $\gamma = 2$ is used in carrying out the variational method to avoid certain mathematical difficulties. However, effect of using $\gamma > 1.405$ is found to compensate partly the effect of using only a finite number of terms in the calculation. It appears that the variational method will give good approximate solutions for thick or thin bodies at low or high subsonic Mach numbers. No experimental comparisons are included. Lester L. Cronvich, USA

3309. **Parsons, D. H., Fluid motions whose kinematics are independent of the compressibility of the fluid,** *Quart. J. Mech. appl. Math.* **3,** part 4, 446–451, Dec. 1950.

Paper gives the answer to following question: What steady motions of a nonviscous compressible fluid may be reproduced exactly by motion of a nonviscous incompressible fluid? By comparison of equations of continuity and motion in both cases, author

obtains three conditions for solution of the problem. Two-dimensional motion is treated in detail and the result is that streamlines should be either concentric circles or parallel straight lines. In case of three-dimensional motion, the only conclusion derived is that the streamlines should be parallel straight lines. For example, any steady flow of a gas in a straight pipe, in which the velocity varies over the cross section in any manner, may be kinematically reproduced by the flow of a liquid in the pipe. The mathematics used is very elementary.

M. Z. Krzywoblocki, USA

3310. Evvard, J. C., Use of source distributions for evaluating theoretical aerodynamics of thin finite wings at supersonic speeds, *Nat. adv. Comm. Aero. Rep.* 951, 32 pp., 1950.

First part of report reviews and extends source distribution methods. Second part deals with steady-state thin-wing problems. Third part approximates integral equation for unsteady upwash and includes solution of approximate equation.

From author's summary by J. A. Lewis, USA

3311. Harder, K. C., and Klunker, E. B., On a source-sink method for the solution of the Prandtl-Busemann iteration equations in two-dimensional compressible flow, *Nat. adv. Comm. Aero. tech. Note* 2253, 10 pp., Dec. 1950.

The recently derived particular integrals of the Prandtl-Busemann iteration equations make possible the extension of the familiar source-sink concept to the solution of the higher-order iteration equations for subsonic potential flow over thin sharp-nose symmetric two-dimensional profiles. An explicit expression is derived for the second-order velocity potential and velocity components, and a method for obtaining the higher-order terms is indicated. The velocity at the surface of the Kaplan bump is evaluated to illustrate the method.

From authors' summary by M. D. Van Dyke, USA

3312. Ferrari, C., On rotational conical flow (in Italian), *Termotecnica* **5**, 2, 64–66, Feb. 1951.

Author was first to apply method of characteristics in asymmetric three-dimensional supersonic flow (body may be yawed or pitched and not necessarily axially symmetric), but his original 1936 paper was restricted to irrotational, potential-described cases [see "Determinazione della Pressione sopra Solidi di Rivoluzione a Prora Acuminata Disposti in Deriva in Corrente di Fluido Compressibile a Velocità Ipersonora," *Atti R. Accad. Sci., Torino*, **72**, 140–163, Nov.-Dec. 1936]. Irrotationality restriction is now removed; resulting equations of motion differ merely in the addition of two simple vorticity-related terms from the equivalent equation derived previously and applied recently to study of wing-body interference [see AMR **3**, Rev. 2414].

Stepwise procedure for construction of the hodographs (characteristics not needed on conical tip of nose) in the various meridian semiplanes through body axis is discussed in full detail to show how effects of vorticity can be accounted for in determination of flow over conical bodies (not necessarily right circular cones), and comparison is made with analogous polished-up, but restricted, procedure presented in the wing-body interference report. No numerical illustrations are provided. Several additional insights are afforded into physical consequences of derived equations; such as that even the meridian plane of symmetry for a conical field is itself a constant entropy surface on which the flow is irrotational.

This new work, besides accounting for vorticity and eschewing linearizations and expansions, removes restrictions of small angles and axial symmetry inherent in previous work of such investigators as Ferri [AMR **3**, Rev. 1321; but see his recent discussion of entropy distributions in the nonaxial symmetric case, AMR **4**, Rev. 1650] and Stone [AMR **1**, Rev. 993], who have come nearest to solving the general problem. R. H. Cramer, USA

3313. Ross, H. R., Gas pipeline flow calculations, *Instruments* **24**, 3, 345–347, Mar. 1951.

Expressions are presented for metering of gas flow in long-distance pipe lines, using friction pressure drop. Applications to flow calculations for lines consisting of different sized sections and for parallel lines are also discussed. Andrew Fejer, USA

3314. Kaye, J., Kennan, J. H., and McAdams, W., Report of progress on measurements of friction coefficients, recovery factors, and heat-transfer coefficients for supersonic flow of air in a pipe, *Trans. Amer. Soc. mech. Engrs.* **73**, 3, 267–277, Apr. 1951.

See AMR **3**, Rev. 1582

3315. Kaletskaya, È. M., On the theory of hydraulic shock in gas conduits (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)*, **72**, 6, 1029–1032, June 1950.

Author reduces the problem considered to the nonlinear partial differential equation

$$Q_{xx} = k^{-1}\{[k/(k-1)]\log Q + (k-1)AQ^{k/(k-1)}\}_{tt} \quad [1]$$

Here the unknown function $Q(x, t)$ is the specific energy connected with the pressure p and density ρ by the equations $\rho Q_x = p_x$, $\rho Q_t = p_t$, k the adiabatic exponent, and A a (small) constant depending on k, the initial radius R_0, thickness δ, and elastic modulus E of the pipe:

$$A = (2R_0/\delta E)[(k-1)/kC]^{1/(k-1)}$$

(C being the constant in the adiabatic relation $p = C\rho^k$). Two approximate integration methods are proposed. (a) Set $Q = c[1 + Q_1(x, t)]$, c a constant, and expand the terms in the right hand side of [1] into Taylor series in Q_1 and neglect powers higher than the first. This leads to the wave equation for Q_1. (b) Set $A = 0$ and solve the equation $Q_{xx} = (k-1)^{-1}[\log Q]_{tt}$ by separation of variables ($Q = X(x)T(t)$). This leads to explicit solutions involving a certain number of arbitrary constants.

Courtesy of Mathematical Reviews L. Bers, USA

3316. Klemm, A., Cataphoresis of gas bubbles, *David W. Taylor Mod. Basin Transl.* 137 (from German), 21 pp., 1949.

Translation from *Phys. Z.* **39**, 22, 783–793, Nov. 1938.

3317. Popov, S. G., Examples of the exterior problem of the aerodynamics of a very rarefied gas, *Amer. math. Soc. Translation* no. 36, 20 pp., 1951.

See AMR **4**, Rev. 812.

Turbulence, Boundary Layer, etc.

(See also Revs. 3283, 3287)

3318. Shvets, M. E., Method of successive approximations for the solution of certain problems in aerodynamics, *Nat. adv. Comm. Aero. tech. Memo.* 1286, 20 pp., Apr. 1951.

See AMR **3**, Rev. 1544.

3319. Tani, I., Water jump in the boundary layer, *J. phys. Soc. Japan* **4**, 212–215, 1949.

Approximate solution of equations for the flow from a point source in a horizontal plane with the boundary-layer approxima-

tion at the plane, a free surface above the plane, and gravity acting.
J. V. Wehausen, USA

3320. **Tani, I., On the solution of the laminar boundary-layer equations,** *J. phys. Soc. Japan* **4,** 149–154, 1949.

Author has extended Howarth's method of approximate solution for laminar boundary-layer flow with a linear velocity distribution outside the boundary layer to the case where the velocity is given by $U = U_0 + cx^n$. Here $n = 2, 4, 8$; U_0, c are constants, and x is the coordinate measured along the surface. The velocity profiles were first calculated exactly by power series and then approximately by Pohlhausen's method. In the second step, author introduced a new parameter $\omega = \sigma^2 U(d^2U/dx^2)/(dU/dx)^2$ in addition to $\sigma = (\theta^2/\nu)\,(dU/dx)$ as was generally used, where θ is momentum thickness, and ν kinematic viscosity coefficient. By successive approximation, skin friction and velocity profile were calculated. Author claims that the separation point determined by his method is considerably later than that found previously.
Y. H. Kuo, USA

3321. **Grodzovskiĭ, G. L., Solution of axisymmetrical problems of free turbulence by the theory of turbulent diffusion** (in Russian), *Prikl. Mat. Mekh.* **14,** 4, 437–440, July-Aug. 1950.

Consider the turbulent spreading of an axisymmetrical jet of an incompressible gas and the turbulent wake flow behind a body of revolution. Assume, according to Trubchikov [*Trudy Central. Aero-Gidrodin. Inst.*, no. 372, 1938], the constancy of the coefficient of turbulent diffusion over the transverse cross section of the flow [cf. also Prandtl, *Z. angew. Math. Mech.* **22,** 241–243, 1942; and Görtler, ibid., **22,** 244–254, 1942] and the validity of the following form for the turbulent shearing stress in the cylindrical coordinates x, r: $\tau_{xr} = \rho l_u v' \partial u/\partial r = \rho \kappa R u_m \partial u/\partial r$, where $\kappa R u_m$ is the coefficient of the turbulent diffusion, v' fluctuation of the transverse velocity, u_m velocity along axis of the jet and along the axis of symmetry of the mean motion in a wake respectively, u velocity in the direction of x, l_u mixture length, ρ density, κ an experimental constant, and R width of the zone of turbulent mixing. Then, using a method of solution similar to that given in "Modern developments in fluid dynamics," edited by S. Goldstein [Oxford, Clarendon Press, 1938, chap. XIII, §§ 254, 255], author gives a solution for both of the above-mentioned problems.

Comparison of the velocity profile so obtained for a symmetrical jet with that given by Tollmien [*Z. angew. Math. Mech.* **6,** 468–478, 1926] on the basis of Prandtl's mixing-length theory and with measured values due to Kuethe [*J. appl. Mech.* **2,** 87–95, 1935], and comparison of the velocity profile obtained for the wake flow with that given by Miss Swain [*Proc. roy. Soc. Lond. Ser. A,* **125,** 647–659, 1929] and the experimental results obtained by Hall and Hislop [*Proc. Camb. phil. Soc.* **34,** 345–350, 1938] favor author's solutions. Namely, it appears from the corresponding figures that solution obtained by author for a symmetrical jet agrees sufficiently well with the calculated results, especially over the middle portion of the jet; further, it is more convenient than Tollmien's solution for calculations. For the wake flow, author's solution agrees more accurately with experimental results than does Miss Swain's solution obtained by mixing-length theory, and the solution of Goldstein [*Proc. Camb. phil. Soc.* **34,** 48–67, 1938] based on the modified vorticity transfer theory.
Eugene Leimanis, Canada

3322. **Stewart, R. W., Triple velocity correlations in isotropic turbulence,** *Proc. Camb. phil. Soc.* **47,** part 1, 146–157, Jan. 1951.

Author has measured triple velocity correlations in turbulence behind grids in a wind tunnel. Results were obtained for three mesh Reynolds numbers with an electronic circuit modified from Townsend's triple correlator. The triple correlation coefficient $h(r) = -\overline{u_1^2 u_1'}/2(\overline{u^2})^{3/2}$ was always positive and a maximum of 0.025 which occurs when the double correlation is approximately 0.3. The maximum value increases as the decay time increases, and decreases as the Reynolds number increases. Experimental data were verified by obtaining check in the von Kármán-Howarth equation.

Data also reported on the double correlation $\overline{u_1 u_1'}/\overline{u^2}$ and the skewness of $(u_1 - u_1')$. The former has been plotted as a single curve for different Reynolds numbers and is consistent with expected relationships. Skewness was calculated from $\overline{(u_1 - u_1')^3}/\{\overline{(u_1 u_1')^2}\}^{3/2}$ and author concludes that there is no justification that skewness is constant. Paper is of special interest because design of electronic correlator is well described and shows advantages of unusually designed electronic circuits in conducting difficult experimental studies.
L. M. Laushey, USA

3323. **Rubesin, M. W., Maydew, R. C., and Varga, S. A., An analytical and experimental investigation of the skin friction of the turbulent boundary layer on a flat plate at supersonic speeds,** *Nat. adv. Comm. Aero. tech. Note* 2305, 38 pp., Feb. 1951.

Methods used by von Kármán, Prandtl, Frankl and Voishel, Wilson and Van Driest to calculate the skin friction are very briefly reviewed; in particular, the basic assumptions involved in each development are compared. Three new solutions are presented. The first follows the method of Frankl and Voishel but, by a change in the method of integration of the momentum integral, extends the validity of the Mach number range. The second assumes that the extent of the laminar sublayer is identical to that in a fluid whose properties are those of the free stream rather than those of a fluid whose properties are determined by the surface temperature. The third new solution assumes the velocity gradient at the interface to be that of the sublayer. It is thus possible to obtain an evaluation of the extent to which the various arbitrary mathematical boundary conditions affect the average skin-friction coefficient. Calculations are made for a range of Mach numbers from 0 to 4 at a fixed Reynolds number of 7×10^6. At a Mach number of 2.5 the skin-friction coefficient, as given by the various formulas, varies from 1.97×10^{-3} to 3.28×10^{-3} when the Reynolds number is 7×10^6.

A description of tests made on a flat plate at $M = 2.5$ over a Reynolds number range from 2.1×10^6 to 6.2×16^6 is given and the method of data reduction explained. These data as well as other experimental data give skin-friction coefficients in excellent agreement with the extended Frankl and Voishel analysis, although the velocity profiles are not coincident.
Ione D. V. Faro, USA

3324. **Rotta, J., Contribution to the calculation of the turbulent boundary layer** (in German), *Ing.-Arch.* **19,** 1, 31–41, 1951.

See AMR **3,** Rev. 2729.

Aerodynamics of Flight; Wind Forces

(See also Revs. 3154, 3286, 3292, 3303, 3304, 3310, 3363, 3364, 3386)

3325. **Stone, R. W., Jr., Burke, S. M., Jr., and Bihrle, W., Jr., The aerodynamic forces and moments on a $^1/_{10}$-scale model of a fighter airplane in spinning attitudes as measured on a rotary balance in the Langley 20-ft free-spinning tunnel,** *Nat. adv. Comm. Aero. tech. Note* 2181, 59 pp., Sept. 1950.

Results indicate that primary effect of rudder reversal is to give a relatively large increment of anti-spin yawing-moment coefficient when compared with magnitude of aerodynamic yaw-

ing-moment coefficient of fully developed spin; the other force and moment coefficients are affected to a much less degree. Increment of yawing-moment coefficient due to rudder reversal increases with decreasing angle of attack. Moving the horizontal tail rearward for this design increases rudder-reversal effectiveness; deflecting the landing flaps reduces rudder-reversal effectiveness. A conservative estimate from the experimental results indicates that a total aerodynamic yawing-moment coefficient ranging from approximately 0.021 to 0.025, against spin, may be required for satisfactory recoveries from steep spins. Larger values of yawing-moment coefficient may be required for flatter spins. The aerodynamic force and moment measurements were in qualitative agreement with free-spinning results as regards spin and recovery characteristics. From authors' summary

3326. Greidanus, J. H., and de Kock, A. C., Catalogue of aerodynamic measurements, *Nat. LuchtLab. Amsterdam Rap.* F. 64, 44 pp., July 1950.

3327. Jones, I. P., Jr., and Klinar, W. J., Spin-tunnel investigation to determine the effect on spin recoveries of reducing the opening shock load of spin-recovery parachutes, *Nat. adv. Comm. Aero. tech. Note* 2051, 29 pp., Mar. 1950.

An investigation has been conducted in the Langley 20-ft free-spinning tunnel to determine whether the effectiveness of a spin-recovery parachute would be influenced by a reduction, through use of a shock absorber, of the opening shock load. In addition, the effects on the parachute-opening shock load of varying the fabric porosity of the parachute canopy and the towline length were investigated. Results of the investigation indicate that a given spin-recovery parachute is equally effective with or without a rubber shock absorber installed in the parachute towline. Increasing the fabric porosity decreases the parachute-opening shock, whereas increasing the towline length increased the parachute-opening shock load. From authors' summary

3328. Johnson, H. S., and Hagerman, J. R., Wind-tunnel investigation at low speed of the lateral control characteristics of an unswept untapered semispan wing of aspect ratio 3.13 equipped with various 25-per cent-chord plain ailerons, *Nat. adv. Comm. Aero. tech. Note* 2199, 32 pp., Oct. 1950.

A wind-tunnel investigation was made at low speed to determine lateral control characteristics of an unswept untapered semispan wing of aspect ratio 3.13 equipped with 25-per cent-chord plain unsealed ailerons having various spans and spanwise locations. In general, changes in wing angle of attack, aileron deflection, aileron span, and aileron spanwise location produced trends in lateral control characteristics that were similar to, but of different magnitude from those for unswept wings of higher aspect ratio. An aileron of a given per cent span was most effective in producing roll when located outboard on wing semispan, and this aileron also retained the greater part of its effectiveness through angle-of-attack range in this spanwise position. Rate of change of hinge-moment coefficient with angle of attack C_{h_α} was relatively unaffected by aileron span and spanwise location. Rate of change of hinge-moment coefficient with aileron deflection C_{h_δ} became more negative as span of outboard ailerons was increased and also as a half-span aileron was moved inboard on the semispan wing.

Results of this investigation indicated that existing empirical and theoretical relationships for predicting aileron effectiveness parameter C_{l_δ} and aileron hinge-moment parameters C_{h_α} and C_{h_δ} for various spans of ailerons gave satisfactory agreement with experimental results. From authors' summary

3329. Goin, K. L., Equations and charts for the rapid estimation of hinge-moment and effectiveness parameters for trailing-edge controls having leading and trailing edges swept ahead of the Mach lines, *Nat. adv. Comm. Aero. tech. Note* 2221, 92 pp., Nov. 1950.

Previously developed linearized equations for conical-flow solutions have been used to calculate the hinge-moment and effectiveness parameters of trailing-edge controls having leading and trailing edges swept ahead of the Mach lines and having streamwise root and tip chords. Equations and detailed charts and an example are presented for the computation of these parameters. Also included is an approximate method by which these parameters may be corrected for airfoil-section thickness.

Deflected controls are assumed to be located either at the wing tip or far enough inboard to prevent the outermost Mach lines from the controls from crossing the wing tip. For either of these locations, the innermost Mach lines are assumed not to cross the wing root chord. The method for determining control hinge moment resulting from wing angle-of-attack loading is valid for wing plan forms having the leading edges swept ahead of the Mach lines and having streamwise tips. The only additional restrictions are that the controls must not be influenced by the tip conical flow from the opposite wing panel or by the interaction of the wing-root Mach cone with the wing tip.

Ammon S. Andes, USA

3330. Lean, D., Stott, J. R., Hufton, P. A., and Johnson, D., An investigation into the suitability of proposed aircraft-design memoranda tests for deck-landing aircraft, *Aero. Res. Counc. Lond. Rep. Mem.* 2407, 55 pp., Oct. 1947, published 1951.

A series of requirements for deck-landing aircraft have been proposed and the suggested program of tests has been carried out on two naval aircraft. Results of these tests are given in this report, and their significance is discussed.

From authors' summary

3331. Hewes, D. E., The effects of mass distribution on the low-speed dynamic lateral stability and control characteristics of a model with a 45° sweptback wing, *Nat. adv. Comm. Aero. tech. Note* 2313, 27 pp., Mar. 1951.

The trends in lateral stability and control produced by large variations of the mass distribution are determined for an airplane model with a 45° sweptback wing. Calculations are made to correlate the trends determined by theory with those determined from low-speed tests of a free-flying dynamic model in the Langley free-flight tunnel.

Fair qualitative agreement is obtained between theory and experiment. As noted by author, the effects of mass distribution on lateral stability and control, as determined in this investigation, apply only to configurations and conditions similar to those used in the tests. Alvin R. Eaton, Jr., USA

3332. Crocco, G. A., Physiological endurance in jet missiles (in Italian), *Termotecnica* **5**, 2, 55–59, Feb. 1951.

As a brief excerpt from an unpublished study on man-carrying missile design, the case of a vertically launched rocket is considered with aid of simplified expressions, which leads author to conclusion that placing humanly bearable "g" restrictions on launching and landing phases of space-ship's trajectory multiplies required mass ratio fantastically. This result is elaborated as a corollary of the well-known maxim that the greatest height, in vacuo, is attained for given mass ratio and exhaust velocity by instantaneously burning of all propellants at launching [see *Aero Digest* **49**, 3, p. 145, May 1, 1945; "Analysis of V-2 performance" by Aldo Vieira da Rosa]. As a palliative to the drastic charge re-

quirements for jet braking on landing, author suggests use of winged missile, or one deriving support from body lift, operating over lengthened-out ranging trajectory.

R. H. Cramer, USA

3333. **Mattioli, G. D., Computation of the field of induced velocity for a rectangular airfoil** (in Italian), *Aerotecnica* **29**, 5, 281–287, Nov. 1949.

3334. **Jones, R. T., The minimum drag of thin wings in frictionless flow,** *J. aero. Sci.* **18**, 2, 75–81, Feb. 1951.

On the basis of linearized wing theory, criteria for the minimum drag of airfoils are derived, subject to certain auxiliary constraining conditions such as given total lift and plan form, given total volume and plan form, and given thickness and plan form. The computation of the drag and the statement of the results depend on consideration of the superposed flow fields of the wing in direct and reversed motion, along the lines used in Munk's proofs of "reversed flow" theorems. Results apply to subsonic and supersonic flow and to unsteady as well as steady flow. A typical result is that for minimum drag with given plan form and volume, the thickness must be distributed in such a way that the pressure gradient of the superposed flow fields in the direction of flight is a constant over the wing. A. H. Flax, USA

3335. **Graham, D., A modification to thin-airfoil-section theory, applicable to arbitrary airfoil sections, to account for the effects of thickness on the lift distribution,** *Nat. adv. Comm. Aero. tech. Note* 2298, 17 pp., Feb. 1951.

This report modifies the work of H. Julian Allen [AMR **3**, Rev. 86] to account for thickness in the lift distribution. The boundary condition applied is $(v/V_f) = y_c' - \alpha$ instead of $(v/V_0) = y_c' - \alpha$ where v is the induced downwash; y_c' is the local slope of the mean camber line; α is the angle of attack of the chord line; V_0 is free-stream velocity; V_f is the local velocity at the surface of the base profile; the base profile is the profile which would exist if camber and angle of attack were zero. The so-called basic lift distribution is computed by applying the new boundary condition, but the additional lift distribution is found to be too complicated; and so additional lift is found merely by multiplying the vorticity distribution by V_f/V_0. The results agree more closely with experiment than those of Allen.

Theodore R. Goodman, USA

3336. **Pierce, H. B., Gust-tunnel investigation of a wing model with semichord line swept back 60°,** *Nat. adv. Comm. Aero. tech. Note* 2204, 15 pp., Oct. 1950.

An investigation was made in the Langley gust tunnel of a 60° sweptback wing model to determine the effect of a large angle of sweep on gust loads. On the basis of the results, a simplified method of analysis, which uses a slope of the lift curve derived by the cosine law and which uses strip theory to estimate the penetration effect, appears to be applicable to the prediction of gust loads on wings swept as much as 60°. A summary curve representing the results of investigations with wing models having from 45° sweepforward to 60° sweepback is presented.

From author's summary

3337. **Hills, R., Brown, E. C., Morrison, M. A., and Becker, R. V., Wind-tunnel tests on the experimental high lift M.18,** *Aero. Res. Counc. Lond. Rep. Mem.* 2453, 13 pp., June 1942, published 1951.

Wind-tunnel tests have been made on an experimental high-lift design with a 40% chord slotted flap, inset ailerons, and full-span leading-edge slats. Measurements were made with flaps down only, and included: (1) Effect of slipstream on longitudinal stability and trim; (2) yawing and rolling moments due to sideslip; (3) rudder power with and without slipstream. Results are: (1) Maximum lift coefficient is 3·5 both with and without a split flap under the body. (2) Longitudinal stability is adequate except near the stall. Change of stability and trim due to slipstream is small. (3) Ground effect has been estimated and there appears to be sufficient elevator power to get the tail down for landing. (4) n_v is large ($10^3 n_v = 145$) and l_v small ($10^3 l_v = -50$ to -8). (5) Rudder power is sufficient to correct the adverse yaw due to ailerons and the ground swing due to slipstream.

From authors' summary

3338. **Neumark, S., Critical Mach numbers for swept-back wings,** *Aero. Quart.* **2**, part 2, 85–110, Aug. 1950.

Lucid account of extension of linear perturbation theory to three-dimensional nonlifting wings, using source-sink method. For aspect ratios above 2, simple two-dimensional sweep theory closely approximates velocity distribution over most of plan form. Center "kink" region involves greater disturbances. Error in Ludwieg's calculation of kink effect [*M.A.P. Völkenrode Rep. R. & T.* 84. GDC 10/4258 T] is corrected. Isobars and pressure distributions are shown for various untapered sweptback and straight tapered wings of biconvex parabolic section.

Critical Mach numbers are calculated using Göthert's extension of Prandtl-Glauert rule. Although "upper critical" Mach number (corresponding to quasi-two-dimensional region) can exceed unity, "lower critical" Mach number (at kink) must be less than unity. M. D. Van Dyke, USA

3339. **Hilton, W. F., Measurement of downwash at a Mach number of 1.45 behind two wings of finite span,** *J. roy. aero. Soc.* **55**, 481, 43–51, Jan. 1951.

Downwash angles $1^1/_2$-chord lengths behind trailing edge of two rectangular wings with square and 20° raked tips were measured at angles of attack of 0°, 5°, and 10°. Experimental technique is admitted to be crude, but conclusions are nevertheless quite specific. Statement that downwash predicted by linearized theory is in good agreement with measurements is not established by comparison presented. Results prove little more than fact that downwash exists in an inboard region of tip Mach cone and that upwash occurs outboard of tip.

Wallace F. Davis, USA

3340. **Nickel, K., Solution of minimum problems in wing theory** (in German), *Z. angew. Math. Mech.* **31**, 3, 72–77, Mar. 1951.

In "Tragflügeltheorie I," Prandtl gives the following as the third fundamental problem of wing theory: "Given the total lift and the wing span, as well as ρ and V; to determine that distribution of lift on the span for which the drag becomes a minimum." Author extends this problem to include a finite number of auxiliary conditions. Three simple applications are given. They are to find the loading on a given span for which the drag is a minimum holding constant (1) the rolling moment, (2) the total lift and the bending moment at the wing root, (3) the total lift and the pitching moment of a curved wing.

The second-mentioned example has also been treated recently by R. T. Jones [see Rev. 3343 in this issue].

John R. Spreiter, USA

3341. **Teisseyre, J., Influence of wing aspect ratio on the useful load of an airplane** (in Polish), *Arch. Mech. stos.* **2**, 4, 273–317, 1950.

Paper reviews problem of determining optimum aspect ratio of aircraft, particularly long-range transport and bomber types.

Maximum useful load is criterion established. Influence of structural and aerodynamic properties of wings are considered. Paper appears to omit any bibliography of extensive earlier works on this subject. M. J. Thompson, USA

3342. Neel, C. B., Jr., and Bright, L. G., The effect of ice formations on propeller performance, *Nat. adv. Comm. Aero. tech. Note* 2212, 96 pp., Oct. 1950.

Measurements of propeller-efficiency loss due to ice formation are supplemented by an analysis to establish the magnitude of efficiency losses to be anticipated during flight in icing conditions. Measurements were made during flight in natural icing conditions; whereas analysis consisted of an investigation of changes in blade-section aerodynamic characteristics caused by ice formation and resulting propeller-efficiency changes. Agreement in the order of magnitude of efficiency losses to be expected is obtained between measured and analytical results. Results indicate that, in general, efficiency losses can be expected to be less than 10%; whereas maximum losses, which will be encountered only rarely, may be as high as 15 or 20%. Reported losses larger than 15 or 20%, based on reductions in airplane performance, probably are due to ice accretions on other parts of the airplane.

From authors' summary

3343. Jones, R. T., The spanwise distribution of lift for minimum induced drag of wings having a given lift and a given bending moment, *Nat. adv. Comm. Aero. tech. Note* 2249, 14 pp., Dec. 1950.

Author's theory is based on Prandtl's lifting line. In the classical solution for minimum induced drag (the elliptic wing), the downwash is found to be constant. In the present problem, the downwash is found to vary linearly from the bending-moment station to the tip. The results show "a 15% reduction of the induced drag with a 15% increase in span, as compared with results for an elliptically loaded wing having the same total lift and bending moment." The ingenious way in which author has avoided using calculus of variations will interest the theorist.

T. R. Goodman, USA

3344. Küchemann, D., and Weber, J., On the chordwise lift distribution at the centre of swept wings, *Aero. Quart.* **2,** part 2, 146–155, Aug. 1950.

It is shown that load distribution over the root section of a swept wing cannot be obtained from a distribution of bound vortexes having a sharp kink at the root section because of the local discontinuity of the vorticity vector. Based on an examination of this analysis and of some experimental data, a simple empirical equation is proposed for the chordwise load distribution over the root section of a wing with arbitrary angle of sweep.

Gerald E. Nitzberg, USA

3345. Sivells, J. C., and Westrick, G. C., Method for calculating lift distributions for unswept wings with flaps or ailerons by use of nonlinear section lift data, *Nat. adv. Comm. Aero. tech. Note* 2283, 63 pp., Jan. 1951.

Method, based upon lifting-line theory, described in *NACA Rep.* 865, is extended to include wings with partial-span flaps or ailerons. Simplified computing forms are given for both symmetrical and asymmetrical spanwise lift distributions.

Gerald E. Nitzberg, USA

3346. Fusfeld, R. D., A method of calculating the landing flare path of an airplane, *Aero. Engng. Rev.* **10,** 2, 25–30, Feb. 1951.

Landing flare path is obtained by integration of perturbation equations of motion, under reasonable engineering simplifications. Several cases are studied. Martin D. Schwartz, USA

3347. Miele, A., On the speed of an airplane in steady flight, *J. aero. Sci.* **17,** 12, 808–809, Dec. 1950.

Equations for flight speed, radius of turn, and angular velocity are developed in terms of two fundamental parameters. First parameter is theoretical maximum speed for a given net thrust, assuming no induced drag nor compressibility effects. Second is the actual lift-drag ratio as a fraction of maximum lift-drag ratio. Relationships are systematically derived by elementary algebraic manipulation for flight along a right circular helix (the most general constant speed flight) after making conventional assumptions with regard to induced drag. Author gives tables of expressions for basic parameters in terms of thrust, weight, and angles of climb and bank for special cases of general problem. Aside from trivial typographical errors, reviewer notes that first radical sign in equation (11) of paper should include remainder of that equation, while vertical diving angle should be $\pi/2$. Reviewer believes that author's development, with intermediate steps included, is useful and concise material of desirable generality for presentation in courses of instruction in aerodynamics and airplane performance. T. F. O'Brien, USA

3348. Gates, O. B., Jr., and Schy, A. A., A theoretical method of determining the control gearing and time lag necessary for a specified damping of an aircraft equipped with a constant-time-lag autopilot, *Nat. adv. Comm. Aero. tech. Note* 2307, 38 pp., Mar. 1951.

A numerical method is applied to the stability equations of an airplane with autopilot which gives rudder control proportional to the yawing angular acceleration. Method agrees well with airplane motions calculated by a step-by-step procedure. Curves of constant damping are shown in a K-T plane (K control gearing, T time lag) and give more than one range of time lag. Usually, range with smallest time lag is applicable, the other only in special cases. [See also AMR **3,** Rev. 2448.]

W. Oppelt, Germany

3349. Tucker, W. A., and Nelson, R. L., The effect of torsional flexibility on the rolling characteristics at supersonic speeds of tapered unswept wings, *Nat. adv. Comm. Aero. Rep.* 972, 28 pp., 1950.

See AMR **3,** Rev. 1763.

3350. Sissingh, G. J., Note on "longitudinal stability of autopilot-controlled aircraft," *J. aero. Sci.* **18,** 1, p. 65, Jan. 1951.

Author indicates that linear first-order differential relationship between signal and control surface motion assumed by Vazsonyi [see AMR **4,** Rev. 2162] is realized in Bell helicopter rotor system. Also, for any mode of oscillation, autopilot can be replaced by ideal control device (no time lag) giving same aircraft oscillation.

E. T. Welmers, USA

3351. Scull, W. E., Relation between inflammables and ignition sources in aircraft environments, *Nat. adv. Comm. Aero. tech. Note* 2227, 126 pp., Dec. 1950.

A literature survey was made to determine the relation between air-craft ignition sources and inflammables. Available literature applicable to the problem of aircraft fire hazards is analyzed and discussed. Data pertaining to effect of many variables on ignition temperatures, minimum ignition pressures, minimum spark-ignition energies of inflammables, quenching distances of electrode configurations, and size of openings incapable of flame propagation are presented and discussed. Ignition temperatures

and limits of inflammability of gasoline in air in different test environments, and the minimum ignition pressure and the minimum size of openings for flame propagation of gasoline-air mixtures are included. Inerting of gasoline-air mixtures is discussed.
From author's summary

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 3212, 3349)

3352. **Teichmann, A., State and development of flutter calculation,** *Nat. adv. Comm. Aero. tech. Memo.* 1297, 26 pp., Mar. 1951.
Translation from *Lilienthal-gesell. für Luftfahrtforsch. Ber.* 135, 1941.

3353. **Nekrasov, A. I., Application of the theory of integral equations to the calculation of the critical flutter velocity of an airplane wing** (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* 4, 1, 3–45, 1947.
In the present work the problem of flutter of a wing is reduced to the solution of a system of two homogeneous linear integral equations. The distinguishing feature of this method is that preliminary determination of the forms of bending and twisting of the airplane wing are unnecessary. The work contains a detailed description of the procedure to be followed in obtaining numerical results.
Courtesy of Mathematical Reviews From author's summary

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 3145, 3280, 3297, 3301, 3302, 3305, 3342)

3354. **Hubbard, H. H., and Regier, A. A., Free-space oscillating pressures near the tips of rotating propellers,** *Nat. adv. Comm. Aero. Rep.* 996, 21 pp., 1950.
See AMR **3,** Rev. 563.

3355. **Delano, J. B., and Carmel, M. M., Tests of two-blade propellers in the Langley 8-foot high-speed tunnel to determine the effect on propeller performance of a modification of inboard pitch distribution,** *Nat. adv. Comm. Aero. tech. Note* 2268, 67 pp., Feb. 1951.
Results are presented of high-speed wind-tunnel tests of two specific model propellers differing in inboard pitch distribution. The higher efficiency of one of the propellers at high speeds was attributed to the higher load-carrying capacity of the inboard sections after compressibility losses had occurred in the outboard region. A classified report covering this work has been available for some six years. John V. Becker, USA

3356. **Duncombe, E., A method of estimating optimum turbine operating conditions for a range of nozzle and blade angles,** *Nat. Res. Counc. Canada Rep.* MT 13, 37 pp., June 1950.
Author reduces blade data to turbine design specifications. He treats fluid flow considerations only, and there is no serious treatment of strength problems. Analytical treatment of both compressible and incompressible flow, following usual one-dimensional approximation is limited apparently to single-stage turbines.
Detailed application to British and German turbine data of 1945–1949 is included. Method may be applied to any comprehensive set of data, but reviewer doubts that method involves less labor than other methods. (Appendix shows 52 calculations per point. Method requires many points to determine optimum.)
W. Kenneth Bodger, USA

3357. **Ainley, D. G., An approximate method for the estimation of the design point efficiency of axial flow turbines,** *Aero. Res. Counc. Lond. curr. Pap.* 30, 16 pp., Aug. 1949, published 1950.
An empirical method of predicting the efficiency of conventional-type axial-flow turbines is suggested. Values of efficiency so deduced are calculated in accordance with measurements of pressure-loss coefficients in turbine blades obtained from cascade tunnels and from some experimental turbine test data. For a number of existing turbines a comparison has been made between predicted efficiencies and efficiencies actually recorded on test. As a result of this comparison a final empirical correction to the calculated efficiencies is suggested.
Calculations indicate the influence of the nozzle-outlet angle and of the turbine-stage temperature-drop coefficients on turbine efficiency. The highest calculated efficiencies occur with 50% reaction turbines for high gas-outlet angles and moderate temperature-drop coefficient. This analysis indicates that a turbine having high reaction and a low value of temperature-drop coefficient will result in a more efficient engine than a turbine of minimum size and weight with a high temperature-drop coefficient. H. E. Sheets, USA

3358. **Panetti, M., A limit hypothesis for calculation of the characteristic of axial compressors** (in Italian), *Termotecnica* 5, 1, 5–10, Jan. 1951.
Based on assumption of constant discharge angle, the pressure-volume characteristic of an axial blade cascade is calculated. The assumption is confirmed by cascade tests and can be considered as a fairly good approximation for cascades with chord-to-pitch ratios not much below 1, operating in unstalled range of flow. The influence of friction losses on the characteristic is taken into account by assuming a reduction of exit area due to boundary layer. E. Haenni, Switzerland

3359. **Boxer, E., Influence of wall boundary layer upon the performance of an axial-flow fan rotor,** *Nat. adv. Comm. Aero. tech. Note* 2291, 21 pp., Feb. 1951.
Experimental investigation of effect of wall boundary layer (artificially introduced by spoilers) on the performance of a single axial-flow fan rotor designed for no boundary layer. The loss of rotor efficiency is found to be small. Hsuan Yeh, USA

3360. **Chien, W.-Z., The true leaving angle for diaphragm and bucket wheel with curved guides at the discharge end,** *Engng. Reps. nat. Tsing Hua Univ.* 4, 1, 78–102, Oct. 1948.
Author deals with an approximate method, using conformal transformation, to discuss the flow beyond the discharge side of lattice blades of diaphragm and bucket wheel, when two-dimensional, nonviscous, and nonrotational flow is supposed. Theoretical considerations show how to find the actual discharge of the flow from a lattice system of curved blades. A numerical example is given. As the author's method is based on different assumptions to simplify the problem, the reviewer believes an experimental control, not stated in this paper, would be interesting.
E. Mühlemann, Switzerland

3361. **Šidlik, F., Turbocompressor with dehumidification of compressed air,** *Engng. Rev. Prague,* no. 2, 17–23, Apr. 1950.
Use of compressed air without dehumidification, compressed air with dehumidification, and electrical machinery in mining operation is discussed. Compared with ordinary air installations, use

of dehumidified air permits lower air consumption, less icing trouble, and use of cold exhaust air to achieve lower temperatures within mines.

Efficiency of system utilizing dehumidified air in machines with expansion (partial-stroke admission) is shown superior to ordinary system utilizing full-stroke admission. Cost of the three systems are compared, and additional safety and comfort of working conditions with cooler air attained using dehumidification system are emphasized. K. R. Wadleigh, USA

3362. Sänger, E., Air admixture to exhaust jets (in German), *Ing.-Arch.* **18,** 5, 310–323, 1950.

Article gives theoretical discussion of mixing of parallel gas streams, mixing assumed to be at constant pressure. In part I gas properties of both streams (gas constant R and specific heat C_p) are assumed to be the same, and two cases are discussed—free jet mixing with ambient gas, and mixing of an enclosed jet with induced gas stream. Two cases of the latter are discussed—mixing below and above ambient pressure. Part II discusses the thrust augmentation attainable by mixing of the exhaust jet from a reaction engine (turbojet, pulse-jet, or rocket), or the exhaust of an internal-combustion engine, with gases which are induced to flow through a suitably shaped duct by the exhaust-jet action.

Part III applies the theory numerically to some specific cases of mixing which are potentially useful in engineering practice.

B. W. Augenstein, USA

3363. Plaskowski, Zb., On the use of rocket assists in fighter aircraft (in German), *Flügwehr und Technik* no. 6, 6 pp., 1950.

See following review.

3364. Plaskowski, Zb., The use of auxiliary rockets in high-speed aircraft, *Aircr. Engng.* **23,** 265, 72–75, Mar. 1951.

Because of their high specific fuel consumption, rockets are adaptable mainly as an auxiliary to gas turbines for increasing the thrust. Basic advantage of rockets is that while their thrust is independent of flying speed, it increases with altitude. Hence, thrust augmentation of rockets is most effective in high-speed, high-altitude flight. Results of performance calculations of an aircraft equipped with a gas turbine and two auxiliary rockets are given in detail. These illustrate the following effects of the rockets: Reduction of time and distance for take-off; increase of rate and angle of climb with consequent reduction of time required to reach a given altitude; increase of ceiling; and reduction of radius of turn and time to turn in high-speed flight.

Morris Morduchow, USA

Flow and Flight Test Techniques

(See also Revs. 3298, 3323, 3325, 3331, 3337, 3381, 3386, 3400

3365. Katzoff, S., Gardner, C. S., Diesendruck, L., and Eisenstadt, B. J., Linear theory of boundary effects in open wind tunnels with finite jet lengths, *Nat. adv. Comm. Aero. Rep.* 976, 37 pp., 1950.

See AMR 2, Rev. 790.

3366. Mair, W. A., The design of fans and guide vanes for high-speed wind tunnels, *Aero. Res. Counc. Lond. Rep. Mem.* 2435, 27 pp., June 1944, published 1951.

Report describes method which has been used at the Royal Aircraft Establishment in designing fans and guide vanes for wind tunnels having maximum speeds above about 300 fps. The rotational speed of the fan is determined only by the choice of the tip speed which, in turn, is limited, as excessive noise or shock stalling of the fan blades should be avoided. Effects of compressibility and blade interference are considered in detail and the method of design is fully explained. It is assumed without proof that the air density at the fan is the mean value of the densities before and after the fan. Reviewer remarks that the quality of the airstream in the wind tunnel can be improved considerably if the fan is designed in such a way that, if possible, the velocity- and static pressure distribution after the fan is made uniform (these distributions before the fan may be measured on a model of the tunnel). This procedure is the more urgent when the diffuser after the fan has a greater apex.

S. I. Wiselius, Netherlands

3367. Dickinson, D. R. H., Prototype testing of aircraft, *J. roy. aero. Soc.* **54,** 474, 359–370, June 1950.

3368. Hermann, R., Diffuser efficiency and flow process of supersonic wind tunnels with free jet test section, *A. F. tech. Rep.* 6334, Dec. 1950.

A theoretical analysis is given for the flow in one type of supersonic tunnel. Diffuser efficiency is calculated for the case of equilibrium between test-chamber pressure and pressure in the nozzle exit, assuming one-dimensional, steady, frictionless flow. In the recapturing zone of the diffuser a transition occurs from supersonic to subsonic flow, which is followed by an acceleration in the convergent portion up to sonic velocity at the second throat. The transition is not a normal shock and involves a loss greater than that of a normal shock at the test-section Mach number.

A comparison of the analytical and experimental results for wind tunnels up to Mach number 4.4 shows good agreement.

R. C. Binder, USA

3369. Peterson, R. F., The boundary-layer and stalling characteristics of the NACA 64A010 airfoil section, *Nat. adv. Comm. Aero. tech. Note* 2235, 16 pp., Nov. 1950.

Tests in a wind tunnel were made at a Reynolds number of 4.1 million and included force measurements, pressure-distribution measurements, flow studies by liquid-film technique, and boundary-layer measurements. A small region of separated flow was evident near the leading edge on upper surface of the airfoil at positive angles of attack; this region moved forward and became narrower as the angle of attack was increased. At an angle of attack of 9.5° the separated flow failed to reattach to surface, causing stall. Since there was no turbulent separation at trailing edge, lift-curve peak was sharp and stall occurred suddenly and with no warning. From author's summary

3370. Wuest, W., Glass spring manometers (in German), *Arch. tech. Messen* **168,** p. 1, Jan. 1950.

3371. Fauquet, A., Measurement of pressure averages and differences (in French), *Rech. aéro.*, no. 18, 59–64, Nov.-Dec. 1950.

Mean pressure between two points, situated in a uniform stream, can be read at a collector, connected with the two points by identical transmission pipings, each consisting of a first tube of radius R and length L, and a second one, of radius r and length l; the difference of pressures is read at a differential manometer connected between the ends of the tubes of radius R. In the pipings, the flow has to be of the parallel type and the kinetic

energy negligible in comparison to the head loss. Author gives two charts for determination of the dimensions of the pipings. He describes two constructions of meters of particularly small dimensions. A. Schlag, Belgium

3372. **Murdock, J. W., and Fiock, E. F., Measurement of temperatures in high-velocity steam,** *Trans. Amer. Soc. mech. Engrs.* **72,** 8, 1155–1161, Nov. 1950.

Studies have been made of the performance, in moving air and steam, of various total-temperature-type wells suitable for use in steam at operating conditions. The instruments recommended for such applications, constructed so that the sensing element is surrounded by nearly stagnant steam, have temperature-recovery factors above 0.9, which do not change significantly with either the medium, its temperature, or its pressure. Although additional work remains to be done on reducing their sensitivity to flow direction and pattern, these wells, when installed in straight pipes through which steam is flowing at any velocity up to 725 fps, yield total enthalpies which are accurate to within 1 Btu per lb.
From authors' summary

3373. **Mair, W. A., and Gamble, H. E., The effect of model size on measurements in the R. A. E. high speed tunnel. Drag of two-dimensional symmetrical aerofoils at zero incidence,** *Aero. Res. Counc. Lond. Rep. Mem.* 2527, 15 pp., Dec. 1944, published 1951.

Authors investigate two causes of the discrepancy between rise of airfoil drag as measured in high-speed wind tunnels and in flight, namely: (a) Effect of tunnel walls; (b) difference of Re between tunnel and flight. Three NACA 0015 airfoils of different sizes have been tested at two different Reynolds numbers; from the results, the effects of varying Re and tunnel wall interference have been separated. It appears that the blockage corrections in current use are not large enough to equalize drag measurements with different sizes of airfoil at the same Re; empirically increased corrections are needed. Results also show that at high Mach numbers there is a fairly large variation of C_D with Re, especially between $Re = 0.2 \times 10^6$ and 1.4×10^6.
B. G. van der Hegge Zijnen, Holland

3374. **Gast, Th., and Vieweg, R., Remote measurement of rate of flow by electrical means** (in German), *Feinwerk Tech.* **54,** 10/11, 261–267, Oct.-Nov. 1950.

Paper describes two flow-measuring instruments for special uses. First consists of spring-supported circular disk placed normal to flow direction. Deflection of disk by impact force is transmitted by variable resistor to bridge circuit. Temperature compensation in bridge circuit and correction for fluid density change with temperature are provided. Method can also be used to measure ratio of two simultaneous flows by means of a double bridge. It gives accurate results in flow range where drag coefficient of disk is constant.

Second instrument involves measurement of inductive effect produced by flow of conductor through a magnetic field. This is suitable for measurement of flow of acids or bases. Difficulties of the method are discussed. A. Shaffer, USA

3375. **Hooper, L. J., Calibrations of six Beth-Flow meters at Alden hydraulic laboratory, Worcester Polytechnic Institute,** *Trans. Amer. Soc. mech. Engrs.* **72,** 8, 1099–1110, Nov. 1950.

Six Beth-Flow tubes were calibrated by means of a volumetric tank at the Alden Hydraulic Laboratory to determine their suitability as flow-metering elements. Four of the six meters tested had practically the same coefficients with flow in either direction. The flow coefficients were constant above a Reynolds number of 100,000. Further tests are necessary to determine manufacturing tolerances and the effects of disturbed flow due to various types of piping arrangements. From author's summary

3376. **Sanders, J., and Pounder, J. R., Wall interference in wind tunnels of closed rectangular section,** *Nat. Res. Counc. Canad. aero. Rep.* AR-7, 62 pp., 1949, published 1951.

Theories of the wall interference on airfoils and symmetrical bodies in wind tunnels of closed rectangular section are reviewed and extended. In part 1, exact and general expressions are derived, on the basis of lifting-line theory, for the interference on the lift, drag, lift distribution, and rolling and yawing moments of an arbitrary three-dimensional airfoil. Part 2 contains lift, pitching-moment, hinge-moment, and pressure-distribution corrections for a two-dimensional airfoil spanning the tunnel. The theories of parts 1 and 2 are combined and extended in part 3 to obtain streamline curvature corrections to the lift, pitching moment, hinge moment, and lift distribution on a wing with a control surface, as well as downwash and tail-setting corrections. Parts 2 and 3 also contain blockage and pressure-gradient corrections for two- and three-dimensional symmetrical bodies, respectively.

Tables and graphs show the results of calculations described in part 4. A comprehensive bibliography is included.
From authors' summary by Theodore R. Goodman, USA

3377. **Kirby, D. A., and Dee, F. W., Low-speed wind tunnel investigation of the change in aerodynamic centre position and in C_{m_0} due to propeller turbine nacelles,** *Aero. Res. Counc. Lond. curr. Pap.* 39, 27 pp., Feb. 1950, published 1951.

Low-speed wind-tunnel tests have been made on the effect of propeller-turbine type nacelles on the position of the aerodynamic center and the pitching moment at zero lift of a multi-engine aircraft. This investigation forms part of a series of tests made to improve stability prediction data, primarily for civil aircraft. A plain rectangular wing was used to test various lengths of nacelle overhang and rear fairing for both chordline and underslung nacelles parallel and drooped at $-4°$ to the wing chordline. Tests were also made with (1) two nacelles on a wing to find the mutual interference between them, and (2) nacelles on both low and high wings on a fuselage to find the interference between the body and a nacelle. The results are presented in a form suitable for predicting the total effect on longitudinal stability of the nacelles of a turbine-driven multi-engined aircraft.
From authors' summary

3378. **Cheers, F., Walker, W. S., and Taylor, C. R., Two-dimensional tests on a 15% thick symmetrical roof-top aerofoil with 20% plain flap in the National Physical Laboratory 13 ft × 9 ft wind tunnel,** *Aero. Res. Counc. Lond. Rep. Mem.* 2412, 10 pp., June 1946, published 1950.

3379. **Stevens, V. I., Hypersonic research facilities at the Ames Aeronautical Laboratory,** *J. appl. Phys.* **21,** 11, 1150–1155, Nov. 1950.

Two wind tunnels recently completed at the Ames Laboratory of the NACA—the 10 by 14-in. supersonic wind tunnel and the supersonic free-flight wind tunnel—are capable of providing test Mach numbers well in excess of 5. Since such facilities are relatively uncommon, paper is devoted primarily to describing these wind tunnels and their associated equipment. Treatment of the 10 by 14-in. supersonic wind tunnel is concerned mainly with design and operation of the nozzle and diffuser which provides Mach numbers of 3.5 to about 8. Some mention is also made of the pressure-measuring and flow-visualization equipment. In

case of the supersonic free-flight wind tunnel, high test Mach numbers are obtained by firing models at high speed into an oncoming supersonic airstream. Consequently, main emphasis is placed upon launching techniques, available range of test conditions, and methods of obtaining data.

From author's summary

Thermodynamics

(See also Revs. 3301, 3313, 3387, 3400)

3380. Brown, C. L., Basic thermodynamics, New York, London, Toronto, McGraw-Hill Book Co., Inc., 1951, x + 266 pp. $4.50.

3381. Curcio, J. A., Stewart, H. S., and Petty, C. C., A method for the determination of flame temperature from emission in the ultraviolet OH band, *J. opt. Soc. Amer.* **41,** 3, 173–179, Mar. 1951.

A new method of flame-temperature measurement, using the emission in the ultraviolet due to neutral OH radical, has been developed and instrumented at the Naval Research Laboratory, Washington, D. C. The use of OH emission makes this method particularly suited to nonluminous flames. Preliminary test on steady flames showed close agreement with the sodium line-reversal measurements. High-speed measurements have been made in the range 2000 K–3000 K with a time resolution of 0.1 millisecond and an estimated accuracy of 2 to 10%, depending on flame emissivity.

From authors' conclusion by Antoni K. Oppenheim, USA

3382. Chambadal, P., Thermodynamics of gas turbines (Thermodynamique de la turbine à gaz), Paris, Hermann & Cie, 1949, 315 pp. 1700 fr.

This work deals almost exclusively with the thermodynamic aspect of several gas-turbine and compounded cycles. No description or discussion of machines or components is given. Even subjects lending themselves to theoretical treatment, such as gas dynamics applied to compressors and turbines or heat transmission in heat exchangers, are either omitted or mentioned incidentally.

Chapter 1 deals with the general aspects of the cycle. Chapters 2 and 3 discuss in detail the efficiency of a gas turbine; the question of the reheat coefficient is treated very thoroughly. Chapter 4 deals with air compression with or without intercooling; the theoretically best intercooling conditions are discussed. Chapter 5 covers the simple cycle without heat exchange or reheat, chapter 6 the cycle with reheat, chapter 7 the cycle with heat exchange, and chapter 8 the cycle with heat exchange and reheat.

Chapters 9 and 10 deal with low-pressure cycles, that is, those in which the turbine works between atmospheric pressure and a vacuum provided by a compressor exhausting in the atmosphere, the fluid being cooled between turbines and compressor. Chapter 11 briefly compares the open, closed, and semiclosed cycles, without discussing the engineering factors which might direct the choice to one of them. Chapter 12 deals with gas-turbine cycles compounded with Diesel, free-piston and steam cycles, and chapter 13 with gas-turbine cycles compounded with refrigeration or heating; these two chapters are rather sketchy considering the importance of these compounded cycles and the wealth of information that can be obtained on them by thermodynamics alone.

Book, particularly the first eight chapters, is the work of an intelligent man who has thought deeply about his subject; many remarks and viewpoints are original and interesting. Unfortunately, author has considered efficiency the sole standard of merit in a cycle; no weight has been given to work done per pound of fluid. The conclusions reached in this way are lopsided; the work per pound of fluid determines the size and cost of the machine and is just as important as maximum efficiency. It is, for instance, often better to choose compression ratios for maximum work rather than for maximum efficiency; the more so as maximum work is obtained at lower compression ratios than maximum efficiency, with consequent gain in weight and cost and with an increase in component efficiencies which, in practice, entails a greater thermal efficiency. If author had considered the work per pound of fluid, he probably would not have given so much space to the low-pressure cycles.

The work is essentially theoretical in character; its chief merit is to stimulate thought on thermodynamic cycles. It is, therefore, a pleasant surprise to find an excellent large-scale enthalpy-entropy chart and an explanation for its use in an appendix. The chart is printed in two colors, with the constant-volume lines in red; it is referred to 1 kilogram-molecule of air or combustion gas, a special scale being provided to correct the enthalpy and temperature values according to the air-fuel ratio. This chart is very similar in principle to the excellent Lutz and Wolf charts that could be obtained in Germany before the war; it covers pressures from 0.1 to 100 atmospheres, and temperatures from 0 C to 950 C. Unfortunately 0 C is too high for aircraft turbine work. But on the whole this chart is extremely useful; it would be nice if the publisher were to sell it separately.

Courtesy of Journal of Applied Mechanics

P. F. Martinuzzi, USA

3383. Benitez, L. E., and Penner, S. S., The emission of radiation from nitric oxide: approximate calculations, *J. appl. Phys.* **21,** 9, 907–908, Sept. 1950.

A semi-experimental formula for the emissivity of NO is given. According to the author it should be regarded as a rough approximation. H. C. Brinkman, Indonesia

3384. Penner, S. S., Emissivity calculations for diatomic gases, *J. appl. Mech.* **18,** 1, 53–58, Mar. 1951.

Previously (see preceding review) author has given an approximate calculation of the emissivity for diatomic gases using drastic simplifications, e.g., an average absorption coefficient. In this paper he points out that the simplified procedure yields reliable results even for low total pressures. This is shown by comparison with experiment for CO. H. C. Brinkman, Indonesia

3385. Scheil, E., Thermodynamics and structure of iron-carbon alloys (in German), *Arch. Eisenhüttenw.* **22,** 1/2, 37–52, Jan.-Feb. 1951.

One method of describing the thermodynamics and the structure of iron-carbon alloys is based on the so-called "carbide hypothesis" which assumes that carbon in the melt and in the gamma phase occurs as iron carbide rather than as individual carbon atoms. Since, in many instances, this method fails, author tries to develop an interpretation of the iron-carbon system on the assumption that iron atoms occupy interstitial positions in the lattice, and that the presence of a carbon atom in one such position decreases the probability that the neighboring interstitial positions will be occupied. Using the theory of lattice imperfections of Wagner and Schottky, the equilibrium curves are calculated. It is assumed that carbon can be located in: (a) Fe_4C-site with all neighboring sites vacant; this is the preferred position; (b) Fe_4C_3-site, which is seldom occupied; (c) substitution-site, which is very rare. This thermodynamical theory leads to a good agreement with experiment. R. Smoluchowski, USA

3386. **Stalder, J. R., Goodwin, G., and Creager, M. O., A comparison of theory and experiment for high-speed free-molecule flow,** *Nat. adv. Comm. Aero. tech. Note* 2244, 68 pp., Dec. 1950.

Satisfactory experimental confirmation is obtained of the drag forces and temperatures on a heat-conducting circular cylinder oriented normal to low-density flows of monatomic (He) and diatomic (N_2) gases. Assumption of purely free-molecule flow is justified by the Knudsen numbers (4 to 185) achieved. A wire of 0.0031-in. diam with 15/32-in. exposed length was suspended in jet created by expansion from bottled source through De Laval nozzle into chamber evacuated to pressures between 18.7 and 137 microns Hg; Mach number variations averaged 5% over portion of jet used. Forces were measured with magnetic balance, temperatures with model itself constructed as a thermocouple. Test Mach number [$(2/\gamma)^{1/2}$ times the "molecular-speed ratio," a more meaningful quantity in free-molecule flow] ranged from 0.55 to 2.78.

Temperature data agree well with theory and confirm the significant result that they may exceed adiabatic stagnation temperature of the stream. Drag data agree reasonably well but show systematic deviations from theory, which author explains tentatively. Reviewer regards reproducibility and small scatter of results as remarkable, considering unusual experimental difficulties. H. Ashley, USA

Heat and Mass Transfer

(See also Revs. 3265, 3318, 3415)

3387. **Prigogine, L., De Brouckere, L., and Amand, R., Research on thermodiffusion in liquid phase** (in French), *Physica* 16, 7–8, 11–12; 577–598, 851–860; July-Aug., Dec. 1950.

Experimental and theoretical study of thermal diffusion of binary organic solutions by the thermogravitational method. The Soret coefficient D'/D (D and D' coefficients of diffusion and thermodiffusion) is independent of the composition for nearly perfect solutions but varies considerably with concentration in associated solutions. The constituent with higher density of cohesion (energy of vaporization/molar volume) is enriched at the cold wall. In associated solutions the sign of D'/D can be reversed when passing from low to high concentrations. It is shown that the "forgotten effect," i.e., influence of the concentration gradient on the density gradient, affects the separation curves considerably in some cases. P. Kriezis, Greece

3388. **Sutton, O. G., On the stability of a fluid heated from below,** *Proc. roy. Soc. Lond. Ser. A*, **204,** 1078, 297–309, Dec. 1950.

The stability of a thin horizontal layer of gas between two plane surfaces with the lower surface hotter is shown to depend upon two criteria and to give rise to two different convective patterns. The analysis of Rayleigh is discussed and shown to apply when the layer is relatively deep, Bernard type cells occurring. For smaller depths; a columnar type of convection occurs at smaller temperature differences than required by the Rayleigh criterion. An empirical analysis yields good predictions for this second type of convection. Myron Tribus, USA

3389. **Manson, S. V., Correlation of heat-transfer data and of friction data for interrupted plane fins staggered in successive rows,** *Nat. adv. Comm. Aero. tech. Note* 2237, 14 pp., Dec. 1950.

Available heat-transfer and friction data on plane fin surfaces that are interrupted and staggered in successive rows in the fluid-flow direction are separately correlated. Data presented are taken from five reference reports and cover wide ranges of flow, Reynolds number, passage hydraulic diameter, fin transverse spacing, fin length in the fluid-flow direction, fin thickness, and various stagger arrangements of the fins.

A single heat-transfer correlation equation is obtained that satisfactorily represents heat-transfer data over entire range of conditions investigated. Friction data require separate correlation equations above and below the transition Reynolds number of 3500, based on the fin-passage hydraulic diameter. Bulk of the friction data available are satisfactorily correlated.

From author's summary

3390. **Codegone, C., On differential equations for heating** (in Italian), *Termotecnica* **4,** 11, 523–524, Nov. 1950.

The differential equations expressing the temporal variation of temperature for two systems between which heat is transferred by means of a convecting fluid are solved after a suitable schematic simplification is employed. M. J. Goglia, USA

3391. **Loeb, A. L., A theory of the envelope type of thermal conductivity tests,** *J. appl. Phys.* **22,** 3, 282–285, Mar. 1951.

The well-known problem of end effects in a cylinder of finite length has been circumvented by the use of spheroidal rather than cylindrical apparatus. After a general theory of heat flow is given, applications demonstrate the mathematical difficulties caused by discontinuities in the curvature of the heat conductor. The suitability of the spheroidal shape is demonstrated. This theorem is applied to find the heat distribution necessary to keep the core of the apparatus at uniform temperature. Because all measurements are made at the thermal equilibrium, a rough estimate is given for the time necessary to reach equilibrium.

From author's summary by S. I. Pai, USA

3392. **Jacq, J., Contribution to the graphical study of variable thermic systems** (in French), *C. R. Acad. Sci. Paris* **232,** 13, 1292–1294, Mar. 1951.

The graphical method by Binder and Schmidt is extended to cases occurring mostly in practice, in which the given variables or constants are the capacity of the caloric source, depending or not on the temperature inside the region to be heated and the caloric characteristics of the surrounding walls. Two problems are principally solved: (1) To determine the characteristics of the source necessary to heat the region to a given temperature, or inversely, (2) to evaluate the fall of temperature after heating is stopped. Method is illustrated by a simple example, where evolution of temperature inside with time can be read easily from graph. L. Jansen, Switzerland

3393. **Kronig, R., and Bruijsten, J., On the theory of the heat and mass transfer from a sphere in a flowing medium at low values of Reynolds number,** *Appl. sci. Res. Sec. A*, **2,** 5–6, 439–446, 1951.

The distribution of temperature associated with a steady enforced convection of heat from a metallic sphere to a liquid in laminar flow is governed by an equation of the form $\nabla^2 T - \epsilon v \cdot \nabla T = 0$; $T(1, \vartheta) = 1$; $T(\infty, \vartheta) = 0$ where $T(r, \vartheta)$ is an unknown function of the spherical coordinates r and ϑ, the vector field $v(r, \vartheta)$ is proportional to the velocity of a viscous liquid flowing about a solid sphere, as derived by Stokes, and ϵ is a small parameter. Authors aim at solving this equation in terms of a series progressing in powers of ϵ. Applying the function $T_0 = 1/r$ as zero approximation (sphere in liquid at rest), correction terms are obtained which, however, fail to vanish at infinity. An alternative zero approximation $T_0 = [\exp(-\frac{1}{2}\epsilon(1 - \cos\vartheta))]/r$ (point source of heat in flowing liquid) yields correction terms proportional to ϵ and ϵ^2 which the authors consider to be satisfactory.

With the notations λ = thermal conductivity, A thermometric conductivity, v_0 velocity of the liquid, α heat-transfer coefficient, r_0 radius of sphere, $Nu = 2r_0\alpha/\lambda$ = Nusselt's number, $Pe = 2r_0v_0/A$ = Péclet's number, the result reads

$$Nu = 2 + {}^1/_2Pe + (581/1920)\,(Pe)^2$$

Measurements by Kramers [*Physica* **12**, p. 61, 1946] made under conditions of turbulence are not directly comparable but still are compatible with the theory. The calculations do not take account of the distortion of Stokes' velocity field due to variation of viscosity with the temperature. Theory admits application to the mass transfer in evaporation or extraction processes.

R. Eisenschitz, England

3394. Knox, R. J., An analysis of temperature distribution in a metal hollow cylinder of finite radius under unsteady-state conditions from E.E.S. data, *J. Amer. Soc. nav. Engrs.* **62,** 3, 587–599, Aug. 1950.

Temperature distribution in steam pipe is computed graphically, using surface conditions obtained from measured surface temperatures. J. A. Lewis, USA

3395. Hulm, J. K., The thermal conductivity of tin, mercury, indium and tantalum at liquid helium temperatures, *Proc. roy. Soc. Lond. Ser. A*, **204,** 1076, 98–123, Nov. 1950.

Described method employs differential gas thermometers to measure the thermal conductivity of metals at low temperatures, with temperature differences of only 0.02 K in the specimen. Experimental curves are presented showing variation of thermal conductivity with temperature between 1.7 and 4.3 K for pure tin, alloys of tin with mercury, pure mercury, alloys of mercury with cadmium and indium, pure indium, and pure tantalum, in both superconducting and normal states.

The normal conductivity of strain-free specimens containing less than about 0.1% of impurity appears to be mainly electronic and to behave roughly in accordance with the theory of Wilson, although notable discrepancies arise in the detailed application of this theory. Ratio of superconducting to normal thermal conductivity varies with temperature roughly in the manner suggested by Heisenberg when the electrons are mainly scattered by impurities, but follows a radically different curve for which no theoretical explanation is yet available, when lattice vibrations are the dominant scattering mechanism.

For impurity contents greater than 0.1%, or severe internal strains, the normal thermal conductivity contains an appreciable lattice component. Behavior of the superconducting curve suggests that where crystal boundaries scatter the lattice waves, the lattice conductivity is unaltered as the metal passes from the superconducting to the normal state, but where electrons scatter the lattice waves, the lattice conductivity is reduced in this transition, possibly because of the increase in the number of scattering centres. Joseph Kaye, USA

3396. Hulm, J. K., The thermal conductivity of a copper-nickel alloy at low temperatures, *Proc. phys. Soc. Lond. Sec. B*, **64,** part 3, 375 B., 207–211, Mar. 1951.

Results are given for the thermal and electrical conductivities of an alloy of 80% by weight copper and 20% nickel at liquid hydrogen and liquid helium temperatures. The temperature range was from 21.9 K to 1.89 K. The rapid decrease in thermal conductivity at low temperatures is the feature of this experiment. Other data and theories are discussed. A. O. Flinner, USA

3397. de Grave, A., Evaluation of walls from the viewpoint of their thermic characteristics (in French), *Ann. Trav. publics Belg.* **103,** 3, 425–447, June 1950.

3398. Mendelssohn, K., and White, G. K., Film transfer in helium II: IV. The transfer rate on glass and metals, *Proc. phys. Soc. Lond. Sec. A*, **63,** part 12, 372A, 1328–1336, Dec. 1950.

Systematic experiments determined the rate of transfer of liquid helium II in the film which covers solid walls in connection with the liquid. The experiments were conducted on small beakers made of glass or metal. The rate of transfer plotted over the temperature has a characteristic shape for all experiments, increasing from the value zero at the lambda point (2.2 K) with decreasing temperature and later on leveling off to a constant value reached at approximately 1.5 K. The absolute values of the transfer rate depended on the wall material and the degree to which adsorbed air was removed. A thoroughly cleaned glass surface had a flow rate of 8×10^3 cm^3/cm sec below 1.5 K; a platinum and a nickel beaker had two to three times this transfer rate when thoroughly cleaned. E. R. G. Eckert, USA

3399. Forstall, W., and Shapiro, A. H., Momentum and mass transfer in coaxial gas jets, *J. appl. Mech.* **17,** 4, 399–408, Dec. 1950.

Mean velocity and concentration distributions have been measured for a round jet of helium-air mixture (10%–90%) entering a lower velocity coaxial air flow (presumably) of low turbulence. The results indicate a ratio of turbulent momentum-transfer coefficient to mass-transfer coefficient of about 0.70, in good enough agreement with previous work on momentum, mass and heat transfer to verify the earlier indications that turbulent transport is virtually independent of the molecular transport properties of the media.

Reviewer's remarks: (1) Bibliography and comparison with previous experiments are usually good. (2) Undue stress seems to be put on comparison with a semi-empirical analysis of Squire and Trouncer [*Aero. Res. Counc. Lond. Rep. Mem.* 1974]. (3) No comment is made on errors introduced by fluctuations into determination of mean velocity and concentration.

Stanley Corrsin, USA

3400. Ballard, S. S., McCarthy, K. A., and Davis, W. C., A method for measuring the thermal conductivity of small samples of poorly conducting materials such as optical crystals, *Rev. sci. Instrum.* **21,** 11, 905–907, Nov. 1950.

Thermal conductivities of from 2 to 500 $\times$ 10^{-4} cgs units are measured by comparing flow of heat through a given sample with that through a standard material. On the basis of repeat runs and checks with literature values, an accuracy of about 5% is estimated for this method. Dimensions of the apparatus limit the face size of both the unknown and standard samples to a maximum of 10 mm square; thicknesses of 2 to 10 mm are suitable. Values at average temperatures between 30 C and 75 C are reported for nine materials: sodium chloride, potassium chloride, potassium bromide, calcium fluoride, lithium fluoride (both air-grown and vacuum-grown), silver chloride, thallium bromide-iodide, thallium bromide-chloride, and fused silica.

From authors' summary

3401. Girton, W. Z., and Potter, J. H., Apparatus and technique for measuring thermal conductivity of powdered material, *Amer. Soc. Test. Mat. Bull.* no. 172, 47–52, Feb. 1951.

In this laboratory apparatus, powdered material is placed in the annular space between a cylinder kept filled with steam and the inner surface of a cooling cylinder concentric with the first. The radial heat flow through the material is measured by finding the heat absorbed by water flowing through the cooling cylinders. Guard-ring arrangements are fitted to eliminate end correction. A vibrator attached to the apparatus keeps the apparent density

constant to 1% for separate fillings of a particular power. Apparatus is assembled, and thermocouples positioned, by means of jigs to insure accurate positioning. Results are reported for calcium carbonate, zinc, copper-copper oxide eutectic, and carbonyl iron at temperatures in the region of 140 F. Authors suggest modifications to cover other test temperatures. Reproducibility of thermal conductivity determinations appears to be generally superior to that obtained by previous workers.

H. A. Nancarrow, England

Acoustics

(See also Rev. 3354)

3402. **Weissler, A., and Del Grosso, V. A., The velocity of sound in sea water,** *J. acoust. Soc. Amer.* **23,** 2, 219–223, Mar. 1951.

Accurate knowledge of local sound velocity is essential for acoustical measurements in ocean. This is not usually observed directly but is calculated from temperature, pressure, and salinity. Authors make laboratory measurements on sea water and on various salt solutions as a function of temperature and salinity. Principal results are: (a) Kuwahara's velocity tables are low by about 3 m/s; (b) dissolved air has negligible effect; (c) velocity of a sea-water sample is that which would be expected if each salt had an independent effect.

Robert W. Morse, USA

3403. **Franz, W., On the theory of diffraction,** *Proc. phys. Soc. Lond. Sec. A*, **63,** part 9, 369 A, 925–939, Sept. 1950.

A new successive approximation method for calculating diffraction of an acoustical or electromagnetic wave is described which yields Kirchhoff's theory as a special case of the first step, but has the advantage of applying as well to non-black bodies and for all wave lengths. Two types of steps are involved; one takes account of boundary conditions and the other makes the solutions satisfy the wave equations. Formulas for obtaining a new approximation from a previous approximation are derived which give Kirchhoff's theory in particularly simple form.

An application to small, perfectly reflecting objects is indicated; for spherical objects the general approximation is given specifically and stated to converge well toward the exact solution. An application to the scalar problem of the diffraction of a plane wave by a perfectly reflecting half plane is given which is compared with the exact solution. The first two approximations for the boundary condition in which the wave function vanishes on the plane are derived and converge reasonably well, but in the third approximation a quantity which must be integrated is singular at the edge of the half plane and leads to logarithmic divergence of the integral. This same edge difficulty appears in the second approximation when the boundary condition is that the normal derivative vanishes on the half plane; this case is also treated. A way of modifying the integrand in the half plane problems is given which permits the approximation to be carried out with improvement of the solution. Another procedure for making the integrals converge adds a Hankel function to compensate the singularity at distance ϵ from the edge, then lets ϵ approach zero, leading to a useful result independent of ϵ. This process can be extended to arbitrary screens.

Paul Marcus, USA

3404. **Tamarkin, P., Boyer, G. L., and Beyer, R. T., Experimental determination of acoustic wave fronts,** *J. acoust. Soc. Amer.* **23,** 1, 7–11, Jan. 1951.

A null-reading electronic instrument with a circuit incorporating a novel phase discriminator has been developed for measuring acoustic wave-front shapes and spacings in water at frequencies from 0.5 to 2.5 mc. The time required for a typical survey has been reduced to about one-third that previously needed in the method due to L. Labau [title source, **17**, p. 19, 1945], which necessitates the accurate location of a variable-sized maximum. An analysis of the phase-discriminator circuit, however, reveals that an excess of electric over acoustic signal eventually causes an operating condition in which no null-current point can be obtained. The mechanism of the additional electric signal picked up by the microphone remains unexplained.

E. G. Fischer, USA

3405. **Verma, G. S., Effects of humidity on ultrasonic absorption in air at 1.46 megacycles,** *J. acoust. Soc. Amer.* **22,** 6, 861–862, Nov. 1950.

Author presents results of his measurements of ultrasonic absorption in air at various relative humidities ranging from zero to 84%. Maximum absorption at 1.46 megacycles (= 0.52 cm^{-1}) is found to occur at 46% relative humidity. Verma obtained his results by using an acoustic resonator interferometer and J. C. Hubbard's method of obtaining the data and of calculating the results. In his excellent Fig. 1 he has plotted one set of data taken at 37.2 C and 46% relative humidity. He did not calculate the wave velocity. Using Fig. 1, reviewer found V_0 to be in good agreement with the best previous determinations. The values of α given by Verma in his Table II are for temperatures near 20 C. He states that the excess of absorption is probably due to influence of water vapor on the oxygen molecules, which decreases the average lifetime of a quantum of their vibrational energy. Reviewer believes that a velocity dispersion could have been detected and measured for this humidity range.

W. H. Pielemeier, USA

Ballistics, Detonics (Explosions)

(See also Rev. 3246)

3406. **Evans, W. M., and Ubbelohde, A. R., Formation of Munroe jets and their action on massive targets,** *Research* **3,** 7, 331–336, July 1950.

Describing some experimental work on bare and lined hollow (shaped) charges, authors discuss the action of jets on metal targets, the stopping power of various materials, the change of shape of the jets in space, and the effect of hollow shape on the jet. The experimental details are given; the type of charge, the target type, the method of mounting, and the mode of analysis of the fragments from the jet are discussed in some detail. The many interesting results include one figure showing the great amount of work-hardening of the target material at and surrounding the crater surface. Bruno W. Augenstein, USA

3407. **Evans, W. M., and Ubbelohde, A. R., Some kinematic properties of Munroe jets,** *Research* **3,** 8, 376–378, Aug. 1950.

A brief description of measurements of the energy and penetration laws for Munroe jets (shaped charges). Energies were measured by measurement of crater volumes, of jet velocities, and of the heat evolved in the target by the jet impact. A short discussion of the penetration and scaling laws is given; interestingly enough, it was found that simple formulas of the form, $D_0^n\alpha$ = constant, held for the spherical caps used, where D_0 is entry diameter of crater of depth α, and n depends on the target material. The relation holds after the jet is well formed and before air slowdown is appreciable. Other charge shapes gave different results. It was also found that all crater dimensions scaled linearly with charge diameter. Bruno W. Augenstein, USA

3408. Podliasky, I., The trajectograph ONERA (in French), *Rech. aéro.* no. 18, 35–43, Nov.-Dec. 1950.

Description of a method to restitute the trajectories of missiles by counting and comparing the relative phases of the ultra high-frequency signals (f = 100 MHz) from a quartz-stabilized airborne transmitter received by four ground stations. Coherent mixing of the incoming signal with a common local oscillator is provided by automatic frequency control of the latter by the received signal. Author believes that simplicity of the airborne part of the apparatus offers some advantages with respect to other t.-f.-Doppler methods with airborne receiving-retransmitting systems ("Verdoppler," "Fizeaugraphe"). Phase counting at ground is provided by electromechanical servos. The relative precision of measurements is estimated up to 10^{-4} for the 10 to 30-km range, but may be still influenced by atmospheric and ground-wave propagations conditions. H. Schardin, Germany

3409. Penney, W. G., and others, A discussion on detonation, *Proc. roy. Soc. Lond. Ser. A*, **204**, 1076, 1–33, Nov. 1950.

W. G. Penney, as introduction to discussion, reviews progress made since beginning of last war in the field of detonation. In particular, he summarizes contributions made in the "hydraulic theory" of detonation and modern concept concerned with the structure of the detonation zone, as, for instance, the von Neumann theory.

Sir Geoffrey Taylor gives a summary of problems involving gas flow and shock waves which can be solved owing to the simplicity of geometry, and points out the similarity between these problems and those associated with detonation.

H. Jones demonstrates that, in calculating pressure rise during detonation of solid explosives, the error introduced by the uncertainty in the equation of state is quite small, and discusses the effect of the lateral expansion of explosive on the detonation velocity and on the shape of detonation front.

W. M. Evans describes various techniques of measuring detonation velocity of solid explosives and discusses a number of experimental results obtained at the Armament Research Establishment, Great Britain.

R. M. Davies and associates present a new method of pressure measurement of detonating gases based on the application of a torsional bar, for which energy dispersion is much lower than that associated with the propagation of longitudinal waves and which should be, therefore, more accurate than the conventional pressure-bar technique. They report, also, preliminary results on measurements of pressures in detonating gases obtained at the University College of Wales, by the use of an electrical modification of the Hopkins pressure bar.

C. A. Adams describes two new streak cameras developed at the Armament Research Establishment, one of which operates at 40,000 rpm with writing speed of 4 mm/μsec, and the other, propelled by an air-driven motor, operates at 80,000 rpm with the speed of 6.5 mm/μsec.

F. B. Bowden reports experiments performed at University of Cambridge on the initiation of explosion in solids and its growth to detonation. Ignition was achieved by impact or by friction. It is shown that, in the first case, temperature rise is due, primarily, to the adiabatic compression of small entrapped gas bubbles and, in the second, temperature rise and, hence ignition, is limited by the melting point of solids subjected to friction. The development of detonation is illustrated by photographs taken on Dr. Courtney-Pratt's image-converter camera.

A. R. Ubbelohde demonstrates that it should be possible to achieve detonation in systems for which the energy release, ΔE, is quite small, providing that the reaction process is performed on a sufficiently large scale, and indicates a geophysical example of such a "weak" detonation wave.

J. S. Courtney-Pratt describes his photographing method, developed at the University of Cambridge for studying fast transient phenomena. The apparatus is based on the application of the image-converter tube combined with a time-base deflection system similar to that used in a cathode-ray oscillograph. The time of resolution achieved, i.e., the minimum interval of time between two events which can be resolved, is of an order of 10^{-9} sec.

In final remarks, A. R. Ubbelohde points out that initiation of explosion in lead azide is achieved by a process quite distinct from "burning" (self-heating) as observed in gases; S. Paterson indicates that, in cases of incomplete confinement, the detonation velocity may be reduced because of energy dissipation, and suggests that this effect should be considered in the theory presented by H. Jones; J. Taylor brings out an experimentally observed problem concerned with the existence of high-and-low-velocity regions in the detonation of condensed explosives; and O. A. Gurton describes some experimental results concerned with the fading of detonation in solid explosives.

Antoni K. Oppenheim, USA

Soil Mechanics, Seepage

3410. Green, L., Jr., and Duwez, P., Fluid flow through porous metal, *J. appl. Mech.* **18**, 1, 39–45, Mar. 1951.

Method is outlined for correlating experimental data obtained in studies of the flow of gases and liquids through porous metals. Correlation is based upon suggestion of Forchheimer that the pressure gradient attending flow of liquid through porous medium can be expressed as function of flow rate by simple quadratic equation. Equation of this type defines two length parameters necessary for characterization of porous structure and permits general definition of Reynolds number for structure of arbitrary complexity.

From authors' summary by John S. McNown, USA

3411. Williams, C. E., Jr., and Bruce, G. H., Carrying capacity of drilling muds, *J. Petr. Technol. Trans.* **3** (192), 4, 111–120, Apr. 1950.

A series of laboratory and field experiments were made to determine minimum annular velocity to remove cuttings. Conclusions reached were that cutting removal increased by (1) turbulent flow in the well annulus, (2) low viscosity and low gel strength, (3) increase in mud way, and (4) rotation of drill pipe.

If turbulent flow can be maintained, an annular velocity slightly greater than the slip velocity of the largest cuttings should keep the hole clean. It is stated that this implies velocity of 100 to 125 fpm rather than the presently used 175 to 225 fpm, but does not state how these velocities are calculated, so leaves an uncertainty as to whether conditions in oversized portions of the open hole have been accounted for. John C. Geyer, USA

3412. Aris, R., Stoppage of the sparking of a drill hole by injection of dense water (in French), *Terres Eaux*, no. 12, 62–74, Dec. 1950.

Theory of the unsteady motion in drill holes reaching confined sands when introducing dense water (water + baryta) at the bottom of the drill holes in order to stop the sparking. Author distinguishes two phases in this unsteady motion: The first begins with the introduction of dense water at the bottom of the drill hole and finishes with its arrival at the top. The second phase begins with this arrival. Author deduces values of the discharge and of the density of the suspension of baryta (dense water) as well as the quantity of dense water and time necessary to stop the sparking. Results of the theory are in good agreement with experiments. L. J. Tison, Belgium

3413. Webber, J. C., Fundamental forces involved in the use of oil well packers, *J. Petr. Technol. Trans.* **1,** 10, T.P. 2710, 271–278, Oct. 1949.

3414. Keller, W. O., and Callaway, F. H., Critical analysis of the effect of well density on recovery efficiency, *J. Petr. Technol. Trans.* 2 (186), 9, 269–280, Sept. 1950.

The various theories as to the well-spacing recovery relationship are reviewed in considerable detail and analyzed in terms of their consistency with modern reservoir engineering concepts. It is concluded that the well-spacing problem must be analyzed in terms of recovery efficiency and that a positive answer to the relation between well density and recovery efficiency is not available from direct comparisons of the production histories of wells and fields.

First part deals with a critical examination of background and logic of the Cutler rule and of similar studies by other authors and of related well-spacing concepts. It is indicated that the variations in recoveries with well density observed by Cutler and others can be logically attributed to regional migration. Theoretical justification of the Cutler-type relation, wherein observed variations in recovery with well density in the same field is attributed to variations in recovery efficiency, in terms of energy relations, is refuted.

Second part reviews concepts of reservoir mechanics with regard to the well-density recovery relation. It is indicated that little variation of recovery efficiency with well density can be expected in a depletion-type reservoir, unless lenticular conditions prevent communication between wells.

Testing techniques are outlined which should indicate whether or not a reservoir is continuous between wells and whether or not satisfactory drainage is being obtained with present spacings. A mass of data of this type indicates continuity to exist in most fields. From authors' abstract by John C. Geyer, USA

3415. Skeib, G., A measuring method for determining heat capacity of the earth by means of a constantly heated test body (in German), *Z. Meteor.* **4,** 1/2, 32–39, Jan.-Feb. 1950.

Under assumption of a thermically homogeneous isotropic infinite medium, integration of the nonstationary inhomogeneous differential equation of heat transfer is given for the case when a constant heat quantity per unit volume and time is supplied to the assumed stratified cylindrical or spherical domains. The influence of the thermic inhomogeneity, produced by introduction of the heating body into the material, is discussed and dimensions of the testing body determined, for which the solutions of the above simplified assumptions may be considered practically valid. Equations thus obtained for the space-time temperature field as function of the thermic constants are then, conversely, considered as the condition equations for heat conduction, thermal diffusivity and, thus, for the heat capacity of the investigated material. A graphical method for a quick determination of these three quantities is given. Finally, the practical experimental setup of the method is discussed.

Translation from author's summary

3416. Davidson, D. T., and Gardiner, W. P., Calculation of standard Proctor density and optimum moisture content from mechanical analysis, shrinkage factors, and plasticity index, *Iowa St. Coll. Bull. Engng. Rep.* **4,** 477–481, 1950–1951.

Authors present an empirical method for improving the validity of equations presented by W. H. Rowan and W. W. Graham [*Civ. Engng., N.Y.* **18,** 450–451, 1948] for calculating standard Proctor density and optimum moisture content of soils in terms of mechanical analysis and shrinkage test values. Correction factors are developed for density and optimum moisture content in terms of the plasticity index, and the relations of Rowan and Graham are rewritten incorporating these correction factors. The improved relations appear to give sufficiently accurate results for many engineering applications.

Y. S. Touloukian, USA

3417. Terzaghi, K., Mechanism of landslides, *Engng. Geol. (Berkey) Volume,* Geol. Soc. Amer., pp. 83–123, Nov. 1950.

Landslides—rapid displacements with well-defined boundaries—are distinguished from creep movement at an imperceptible rate with no sharp boundary. Various processes responsible for landslides are discussed with illustrated examples and references. These include deposition above, excavation below, or increased slope due to crustal tilt, earthquakes, spontaneous liquefaction, reduction in cohesion, and pore pressure from recent loading, drawdown or seepage, particularly in stratified materials. The relation between periodic groundwater fluctuation and landslides is considered. While slides often occur during periods of heavy rain, chief cause may be a more permanent process such as the swelling of clay under reduced pressure. Landslides occur quickly but are preceded by a period of acceleration which could warn of danger.

Prevention of landslides requires co-operation between geologists and soil engineers in making slide-producing processes ineffective. Surface treatment may reduce infiltration and prevent shrinkage cracks due to drying, compaction prevents liquefaction, filters control piping, and, the most troublesome, pore pressure may be reduced by tunnels, galleries, wells, or horizontal drill holes sometimes aided by ventilation, vacuum, or electro-osmosis. Edward S. Barber, USA

Geophysics, Meteorology, Oceanography

(See also Revs. 3290, 3388, 3415, 3417)

3418. Sherman, L., On the propagation of hurricanes, *Trans. Amer. geophys. Un.* **31,** 4, 531–535, Aug. 1950.

3419. Schaaf, S. A., and Sauer, F. M., A note on the tangential transfer of energy between wind and waves, *Trans. Amer. geophys. Un.* **31,** 6, 867–869, Dec. 1950.

Transfer to Stokes-type finite water waves is derived to second-order term in the wave steepness (amplitude/wave length). Formula similar to that of Sverdrup and Munk (for a rough water surface) is thus derived for a smooth water surface (wind less than 5 m/sec) by including effect of wave shape on wind velocity in computing the stress and the effect of the vertical fluid velocity.

Reviewer finds that a term introduced in changing coordinates led to the erroneous conclusion that wind could not generate waves with velocities greater than wind velocities. Also, he feels that criticism of Sverdrup and Munk's work, in which the surface is considered rough so that the stress is a *horizontal* eddy stress with the effect of the wave shape included on the basis of this paper, is premature. John C. Freeman, USA

3420. Arizumi, N., A diagrammatic method of computing vertical motion in the atmosphere and its applications, *Geophys. Mag. Tokyo,* **22,** 2, 131–141, Nov. 1950.

A method similar to that proposed by Panofsky is employed to determine the vertical motions in the atmosphere. The technique assumes adiabatic changes of state. Examples of the method as applied to data from a single station as well as to larger regions are offered. Correlations of vertical motions and moisture content with observed rainfall patterns are given.

Lester Machta, USA

3421. Wieghardt, K., On the propagation phenomena in the ground wind (in German), *Meteor. Rundsch.* **2**, 7/8, 196–198, July/Aug. 1949.

3422. Hollmann, G., Fronts and development phases of a shifting cyclone in attached system of coordinates (in German), *Z. Meteor.* **4**, 1/2, 39–47, Jan.-Feb. 1950.

3423. Doporto, M., Theory and description of a gradient wind computer, *Meteor. Service geophys. Publ. Dublin* **3**, 1, 8 pp., 1950.

A quadratic equation is derived for the gradient wind as a function of the speed of the pressure system, the geostrophic wind speed of the radius of curvature of the isobars, and the wind direction relative to the direction of motion of the center of the pressure system. The isobars are assumed to coincide with the streamlines and the pressure systems are presumed to move without change. A gradient wind computer is described which leads to a rapid graphical solution of this equation.

Courtesy of Mathematical Reviews H. Panofsky, USA

3424. Sanuki, M., Studies on biplane wind vanes, ventilator tubes and cup anemometers (I), *Pap. Meteor. Geophys. meteor. Res. Inst. Tokyo*, pp. 81–132, Oct. 1950.

Theoretical expressions are derived for aerodynamic forces and moments of biplane flat-plate wind vanes and cup anemometers, and for flow through Venturi tubes and cowlings with straight, circular, elliptic, and hyperbolic generating functions. Objectives are formulation of design equations in terms of shape factors, and determination of optimum configurations. Experimental verifications are to be reported in later paper.

Analytical method is essentially that of I. E. Garrick [*Nat. adv. Comm. Aero. Rep.* 542, 1936]. Flow is assumed two-dimensional, frictionless, and incompressible. Velocity potentials and stream functions are found by usual procedure of conformal mapping in complex plane; forces, moments, and rates of flow are computed from these. Numerical examples are given.

Results show that biplane wind vanes with negative splay angles (airfoils diverge downstream) exhibit forces which may exceed sum of forces on two independent monoplanes of same dimensions. Force increases with splay angle, but maximum possible force for given size is obtained with definite relationship between splay angle, chord length, and airfoil separation. Flux through Venturis and cowlings is presented in graphical form as function of generating curve and ratio of throat width to side length. The Robinson factor for 3- and 4-cup anemometers is derived and found to be slightly high when compared with experimental data; this is shown to result from aerodynamic interference and is further analyzed.

Reviewer believes that mathematical treatment, while elegant, is excessively complex for engineers except those well-versed in aerodynamic theory and process of conformal mapping in the complex plane. Paper contains many misprints and misspelled words, and the English is, at times, stilted and difficult to follow.

Earl W. Barrett, USA

3425. Crain, C. M., and Gerhardt, J. R., Some preliminary studies of the rapid variations in the index of refraction of atmospheric air at microwave frequencies, *Bull. Amer. meteor. Soc.* **31**, 9, 330–335, Nov. 1950.

The resonant frequency of a cavity through which air is being drawn is compared with that of a closed reference cavity. A measure is thus obtained of the rapid variation of air moisture since the refractive index at the frequency used depends mainly on amount of moisture present in the air. Some preliminary results are given and show that there is a marked correspondence between air temperature variation and moisture variations.

M. V. Wilkes, England

3426. Benioff, Hugo, Earthquakes and rock creep. (Part I: Creep characteristics of rocks and the origin of aftershocks), *Bull. seis. Soc. Amer.* **41**, 1, 31–62, Jan. 1951.

Mechanical characteristics of rocks depart greatly from simple elastic theory in which strain is proportional to stress and is independent of time. Part I of paper examines possible relationship of this departure to origin of aftershocks and creep characteristics of rocks; while part II, to appear later, will discuss earthquake sequences. Stress and strain behavior of rocks is described by a set of curves depicting elastic- and plastic-flow creep and stress relaxation, and it is shown that aftershocks result from creep of fault rocks. Creep may be purely shearing, purely compressional, or a combination of both, in which case the compressional phase occurs first, followed by other, after an interval of 0.01 to 2.4 days. Purely compressional creep sequences were observed for intervals varying from 70 to 640 days. Creep of rocks is studied by electric analogies and also evaluated by empirical creep functions for elastic flow in tension, compressional strains, and torsional relaxation. In accordance with Reid's elastic rebound theory, that earthquakes are produced by sudden release of energy stored as elastic strain in rock masses of a fault, creep theory of aftershocks is formulated. It is shown that in a given fault system, if elastic strain is fully relieved during fault movement, square root of radiated energy of earthquake $(J)^{1/2}$ is proportional to elastic strain (preceding earthquake) of an element of fault rock. Consequently in a series of shocks, value of $(J)^{1/2}$ for separate shocks represents creep-strain recovery increments of fault rock, and a graph of accumulated sum of these increments plotted against time would represent very nearly the creep-strain recovery curve of the rock. Comparisons of characteristics of six earthquakes as to their magnitude and energy relations are given. S. K. Ghaswala, India

3427. Rikitake, T., A note on the temperature distribution within the earth, *Bull. Earthq. Res. Inst. Tokyo Univ.* **27**, parts 1–4, 17–20, Jan.-Dec. 1949.

Author tries to determine the temperature by supposing that main part of the electric conductivity in rocks is due to the motion of ions in ionic crystals; that the bulk modulus does not depend on pressure; and that the temperature in the earth increases proportionately to depth. He is astonished that the resulting temperature differs from the values found by other methods for the uppermost 800 kilometers of the earth, but agrees that the constants used by him are not accurate. B. Gutenberg, USA

3428. Worzel, J. L., and Ewing, M., Gravity measurements at sea, 1947, *Trans. Amer. geophys. Un.* **31**, 6, 917–923, Dec. 1950.

This is a progress report on a long-range program of gravity measurements at sea. The measurements have been made on board United States submarines by the use of Vening Meinesz pendulum apparatus. Improved timing is provided by a crystal chronometer. Data to determine the second-order correction terms of Browne are observed with the Vening Meinesz long-period pendulum apparatus. A precise depth gage record is made and correlated with the pendulum record. During 1947 the following observations were made: 104 along the east coast of the United States north of Cape Hatteras, 86 along the west coast of South America, and 56 along the north coast of South America.

From authors' summary by James T. Wilson, USA

3429. **Unoki, S., On the variation of sea level caused by the variation of atmospheric pressure,** *Oceanogr. Mag. Centr. Meteor. Observ. Tokyo*, **2**, 1, 1–15, Mar. 1950.

First, several evidences prove that the resistance of water in long wave motion can be expressed as the friction proportional to the velocity of water rather than as the eddy viscosity. An attempt is made next to explain theoretically the variation of water level in the sea caused by traveling disturbances taking this type of friction into account. The result shows that a phase lag is noticed in the variation of water level in comparison with that of the atmospheric pressure, and that this phase lag becomes larger as the velocity of propagation and the period of the pressure wave increase, and smaller as the depth of the sea increases.

In seas adjacent to Japan, S. Ogura has found that this phase lag increases towards the higher latitudes. From the present investigation, however, it can be shown that this phenomenon can be explained both qualitatively and quantitatively by considering the bottom configuration velocity of propagation and period of pressure waves, and the effect of Coriolis forces. Additional investigations are also made for the case of an isolated pressure disturbance and for the influence of land barriers.

Koji Hidaka, Japan

3430. **Wexler, A., Recirculating apparatus for testing hygrometers,** *J. Res. nat. Bur. Stands.* **45**, 5, 357–362, Nov. 1950.

An apparatus developed for producing atmospheres of known relative humidity is described. It was designed, principally, for research on and calibration of radiosonde hygrometer elements at temperatures above freezing, but is equally useful at temperatures down to −40 C. It operates by saturating air at one temperature and then raising the air temperature sufficiently to give any desired relative humidity. The air is recirculated continuously in a closed system. Four identical, but independent recirculating systems are employed. Discrete changes in humidity and temperature are obtained by means of a novel pneumatic valve that permits the hygrometers under test to be switched, easily, from system to system. Checks on the performance of the apparatus by means of the gravimetric method of moisture determination and the psychrometric method show an average difference in relative humidity of ±1.2%.

From author's summary

3431. **James, R. W., On the evolution of tropical cyclones,** *J. Meteor.* **8**, 1, 17–24, Feb. 1951.

Main objective of author is to develop a criterion for the growth of tropical storms. He integrates equation of motion for the case of a steady circular vortex and arrives at an expression which, though identical in form to Bernoulli's equation, has quite a different interpretation since the integration is made in space and not following a particle. This equation and its further manipulation may prove to have general value in vortex problems.

The immediate application in paper is less impressive. Author stipulates three cases: absolute vorticity greater, equal to, and less than zero. He obtains from his equation a criterion that tells, in quantities easily measured (pressure and wind distribution), which of the three possibilities applies in any situation. Then he suggests, following other writers, that a vortex will grow when "particle instability" prevails, i.e., when the vorticity is less than zero. Finally, he shows from surface-wind data, that the vorticity is smaller in young than in full-grown storms and that, at times, negative vorticity actually has been observed.

The reader will question whether author's criterion, derived for a steady circular vortex, can really be used for the purposes described—namely, to judge whether an unsteady, very asymmetric vortex will grow. Apart from the fact that particle instability is merely a hypothesis on the growth of vortexes and neither generally accepted nor proved, author also does not show with data that his criterion really gives the information on the vorticity field which he claims. Herbert Riehl, USA

3432. **Tsuji, M., On the rate of evaporation and condensation of falling drops,** *Geophys. Mag. Tokyo* **22**, 1, 11–14, Oct. 1950.

Author suggests a new semi-empirical formula for the rate of evaporation of a water drop falling in the atmosphere. It is close to the Swedish formula by Frössling when the radius of drops is more than 0.1 mm. Formulas approach each other when the droplets become smaller and remain suspended in the air. The relative values of the concentration of vapor at the surface of drop and that of saturated vapor indicate whether evaporation or condensation takes place.

Formula can be used for calculating rate of growth of cloud particles and degree of supersaturation in convective cloud, particularly for rain-making. Steponas Kolupaila, USA

3433. **Parrott, W. H., Paquette, R. G. and Church, P. E., A meteorograph for low altitude sounding,** *Bull. Amer. meteor. Soc.* **31**, 9, 336–340, Nov. 1950.

A device for captive balloon soundings of temperature in the lower atmosphere is described. A bimetallic temperature element actuates a stylus which records on transparent smoked strips fixed to a drum. The drum is rotated by an aneroid element. Temperature is thus obtained as a function of pressure. Readings are obtained by superimposing record over transparent grid calibrated in terms of temperature and altitude (assumed lapse rate). Probable absolute altitude error is 1.5%, and temperature error (mainly due to lag) is 0.2 C. Simplicity recommends the device where fine structure of lapse rate is not required.

Ferguson Hall, USA

Lubrication; Bearings; Wear

(See also Revs. 3133, 3230)

3434. **Clayton, D., and Jenkins, C. H. M., Physical changes in rubbing surfaces on scuffing,** *Brit. J. appl. Phys., Suppl.* no. 69–77, Jan. 1951.

Cast-iron surfaces rubbing against a steel ball have been found to develop a thin 10^{-4}- or 10^{-5}-in. layer of a "white constituent" when scuffing occurs or is approached. This material has not been fully identified, but the results point to it having a basis of two phases, viz., cementite and a quenched high-carbon ferritic phase developed from austenite, resulting from the high temperature developed by rubbing. In laboratory work, using a 4-ball apparatus modified to take piston-ring segments, this white material was also obtained in some degree with mineral oil under milder conditions than those causing scuffing, but not with the castor oil which proved better in preventing scuffing in running-in an aero-engine. Very excellent microphotographs show a smooth surface of this white material interrupted by cracks where the material has torn out. Paper points out a very interesting effect which should be investigated further.

From author's summary by Erle I. Shobert, II, USA

3435. **Burwell, J. T., and Strang, C. D., Further study of metal transfer between sliding surfaces,** *Nat. adv. Comm. Aero. tech. Note* 2271, 39 pp., Jan. 1951.

A study has been made of the influence of metal transfer between piston ring and cylinder on the formation of metal coatings on certain piston-ring materials during run-in. The technique used was that of making one of the two rubbing surfaces radio-

active and, after test, examining the other surface for radioactivity.

The investigation was carried out in two parts: Firstly, the study of transfer between small cylindrical friction specimens of nitralloy and chromium plate; and secondly, the transfer from such a specimen to aircraft piston rings, both new and run-in.

Tests showed that metal transfer occurred with all combinations of materials studied, and decreased as the hardness of the moving surface decreased. The amount of transfer was roughly proportional to distance traveled by the specimen and tended to decrease at higher rubbing speeds. Between nitralloy and chrome-plated surfaces, more material was transferred from nitralloy to chromium than vice versa, and the amount of transfer depended on the geometry of the chromium surface. Appreciable transfer took place to both nitrided steel and cast-iron piston rings which had already been run in nitrided steel cylinders. The existence of a surface coating in piston rings did not hinder further metal transfer. J. C. Wisdom, Australia

3436. Barwell, F. T., and Milne, A. A., Lubrication with materials in the solid state, *Brit. J. appl. Phys. Suppl.* no. 1, 39–51, 1951.

Coefficients of friction between flat mild-steel surfaces loaded at an average intensity of 40 psi at relative velocities of 0.01 cm/sec and 0.4 cm/sec are determined using talc, vermiculite, flake graphite, paraffin wax, and various metallic soaps as lubricants. Only graphite, the metallic soaps, and paraffin wax are shown to be effective lubricants, and paraffin wax was selected for further study under conditions more in conformity with engineering practice. Results are given of tests in which mild steel treated by tin plating, chromium plating, and phosphating was continuously reciprocated against mild steel both unlubricated and lubricated with paraffin wax. A phosphated surface lubricated with paraffin wax formed the most satisfactory combination, and it is suggested that, under the conditions embraced by the experiments, the porous nature of the surface coupled with the rheological properties of the paraffin wax might be the determining factors in performance. From authors' summary

Marine Engineering Problems

(See also Rev. 3394)

3437. Doust, D. J., Design-analysis diagrams for wide-bladed propellers, *Trans. Instn. nav. Archit. Lond.* **92,** 2, 188–198, Apr. 1950.

Results of Gawn's [title source, 1937] experiments of propellers of ogival sections are charted. For the four ratios of developed blade area to disk area, design-analysis diagrams in the form developed by Burrill [*Trans. Instn. mech. Engrs.*, 1943], are presented by lines of constant $B_p = NP^{0.5}/V_a^{2.5}$, $A_Q = 9.46P/d^2(Nd/1000)^3$ and efficiency on coordinates of pitch ratio and Nd/V_a. The optimum pitch ratios noted from these diagrams are found to lie above those of Froude (for smaller blade-area ratios) in a systematic fashion, while the efficiencies are less. Using the cavitation diagram of Burrill, a method is given for designing such propellers with cavitation limitations.

J. M. Robertson, USA

3438. Barnaby, K. C., Modern methods for computing the surface friction of ships, *Inst. mar. Engrs. Trans.* **62,** 8, 281–290, Aug. 1950.

Author summarizes the more important of the several methods which have been proposed, since Froude's work in 1872, for determination of the surface frictional resistance of ships, and compares the results of the several methods by tables and curves. He points out the different methods now in common use and ends with a plea for the adoption by the model test basins throughout the world of a common basis for evaluating the frictional resistance. F. E. Reed, USA

3439. Servello, A., The length L as an element which influences the wave resistance of merchant ships (in Italian), *Riv. maritt. Suppl. tecn.*, 5–19, Dec. 1950.

Author discusses the different elements which influence the wave resistance of ships: ψ (prismatic coefficient), $V/(L)^{1/2}$, and $D/(L/100)^3$ (D is displacement), and deduces an empirical diagram from which the length of a ship can be found when displacement and velocity are given. L. J. Tison, Belgium

3440. Shearer, J. R., A preliminary investigation of the discrepancies between the calculated and measured wavemaking of hull forms, *N. E. Coast Instn. Engrs. Shipb. Trans.* **67,** part 2, 43–68, Dec. 1950.

Author discusses recent approximate wave-calculating methods by Guilloton and Havelock. The Havelock one is used for calculating wave profiles and wave resistance for mathematical hull forms, the wave resistance of which was calculated earlier by Wigley by means of Michell's expression. With adopted complexity of source-system, wave-resistance calculations by two last-mentioned methods agree well or comparatively well. By towing models once free to trim, the other time preventing sinkage and trim, the discrepancies in question are shown in tables and graphs and are analyzed for resistance and wave profile. Without giving any calculations, author proposes a method to correct results by introducing an additional "line" of discrete sources to be determined by a set of linear simultaneous equations constructed to give required corrections to calculated wave profile.

Discrepancies are to be studied in annexed graphs. More distinct features stated by author seem to be in some cases questionable or diffuse as deduced from these graphs. Method of improving approximation, here only tentatively proposed, has to be put in relation to given features—hull form or original source distribution—before being fit for its purpose.

Einar Hogner, Sweden

Biomechanics

3441. Holubář, J., Equations of muscular contraction, *Acad. tchègue Sci.* **69,** 5–12, 1950.

In a muscle fiber directly stimulated at one end, tension is assumed to develop according to some function of time $f(t)$ and to be propagated down the fiber with constant velocity. Assuming $f(t)$ to be damped sinusoidal, or the difference of exponentials, author predicts the course of development of tension and applies it to data on isometric and on isotonic twitch. Agreement is quite good. A. S. Householder, USA

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